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THE RELATIONSHIPS OF THE AUSTRIC-SPEAKING TRIBES OF INDIA, WITH SPECIAL REFERENCE TO THE MEASUREMENTS OF HOS AND SAORAS.

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Received May 31, 1937.
(Communicated by Prof. Birbal Sahni, D.Sc., Sc.D., F.G.S., F.R.A.S.B., F.R.S.)

The relation between race and language has remained a puzzle to anthropologists. Some have identified groups speaking the same or allied languages as forming one ethnic type, others have denied any significance to language as a criterion of racial distinction. Sir Herbert Risley undertook a systematic inquiry to find out, if people speaking the same language or dialects of the same language, belong to the same race, and his conclusions have been recorded in his *Peoples of India*. He finds, however, that no hypothesis on race origins can be safely based on linguistic evidence and all anthropologists will agree with him.

According to the 1931 census, there were 5,342,704 Austric-speaking people in India. The Austro-Asiatic which includes the Munda-speaking tribes is spoken by 5,333,166, while the Austro-Nesian by 6,542 persons only. The different branches of the Munda-speaking people are the Munda, Ho, Sonthal, Bhumij, Tamaria, Juang and many other tribes like the Bhil and the Korwa who have lost their language but retain much of their traditional culture pattern. They are the most widely known primitive people in Northern India as they have been from very early times migrating far and wide. They supply labour to plantations, mills and factories in Bengal, Bihar, U.P. and Assam. The Sonthals have migrated to the fertile plains of Northern Bengal, where they are found to compete with the semi-Mongoloid Rajbanshis and cognate groups. The Hos are working in the coal and iron mines in Bengal and Bihar and are seen also working in the jute mills of Bengal. The Hos and the Mundas go for work to distant districts of Eastern Bengal and are also recruited for the tea gardens in Assam.

The distribution of the Austric-speaking groups in India to-day, suggests that at some remote prehistoric period, the whole of Northern India was occupied by the ancestors of these tribal groups and that the advent of later strains perhaps led to a dispersal of the original hordes who took shelter in inaccessible hills and fastnesses all over Northern and Central India. As Sir Edward Gait points out in his introduction to the *Mundas and their Country* by

S. C. Roy, " there are indications that Munda languages were formerly spoken in the Gangetic Valley. The ' Pronominalised Himalayan Group ' of Tibeto-Burman languages bear traces of having originally belonged to that family. There are striking points of agreement between the Munda languages and Kanauri which is spoken in the neighbourhood of Simla."

Most of the important Austric groups are found in the Chota-Nagpur Plateau in the Province of Bihar. It is a well-wooded and undulating country, divided and diversified by ranges of hills and traversed by fertilising streams. Here and there one meets with vast semi-globular masses of granite which look like sunken domes of gigantic temples. The Hos are concentrated in the Kolhan Government estate which is a series of fair and fertile plains, often broken, divided and surrounded by hills. The Birhors live in the hills and jungles that fringe the Chota-Nagpur Plateau on the east and the north-east. The Tamarias are found in the Ranchi District as well as in Singbhum. The Mundas have their home mainly in the Ranchi District.

The racial history of the Austric-speaking people has not yet been rescued from the mist of traditional antiquity. They have been described as Pre-Dravidians, Kolarians, Dravidians, Australoids, Kolide and Nishadic. Their racial affinity with the tribal groups of the south has very often been misunderstood and we are yet uncertain as to the racial composition of the different Austric-speaking groups. The Oraons of the Chota-Nagpur Plateau, a Dravidian speaking group, living in the same area and possessing a culture different in some respects from that of their neighbours, the Mundas and the Birhors, have complicated the issue as opinions are still far from unanimous about their relationship with the latter. Recent research into the migrations of South Indian tribes confirms our suspicion that the Oraon, the Gond of C.P. and the Mal and Mal Paharia of Bengal, represent hordes of Dravidian speaking people migrating to Northern and Eastern India in comparatively recent times. The institution of social segregation, *viz.*, the village dormitory found in its pristine form among the Oraon and many tribes of the south and also among the Mongoloid tribes in Assam, has perhaps its own tale to tell, as it is likely that the Austric-speaking groups probably borrowed this institution from the Oraons. Although the *Dhumkuria* (dormitory) is a living institution among the Oraon and forms as it were the pivot of their social organisation it is not commonly met with among the Mundas, the Hos and the Sonthals. Traces of it are found no doubt among the Mundas who live in the same area as the Oraons, but less so among the Hos and practically absent among the Sonthals. The Mundas therefore represent a marginal group, so far as this institution is concerned. The Saoras of the Ganjam Agency tracts who are known to anthropologists

as of the same race as the Oraons possess all the characteristic features of dormitory organisation and its importance in the life of the Saoras has been recorded by most ethnographers who have written on them.

Regarding the racial origins of the Austric-speaking groups, Dr. A. C. Haddon writes,[1] "From the racial point of view the Kolarians can only be placed in the Pre-Dravidian group. They have a dark-brown, almost black skin, coarse black hair inclined to be curly and scanty beard, low medium stature, usually 1·577–1·611 M (but the Hos are tall 1·680 M and the Juangs are short 1·570 M) and sturdy limbs. They are dolichocephalic, C.I. (74·5–76) with a low narrow forehead, irregular features, thick lips, eyes often bright and full and not oblique, and the nose broad and flat (N.I.: Korwa, 92·5; Munda, 89·9; Kharwar, 89·7; Sonthal, 88·8; Bhumij, 86·5), thus all are platyrhine. In spite of the foregoing there is something in the facial appearance of many Kolarians which enables an observer to pick out a typical inhabitant of Chota-Nagpur from a crowd of southern Dravidians and among some (Munda, etc.) there is often a reminiscence of Mongoloid traits. The Oraons who call themselves Kurukh of Chota-Nagpur are physically Pre-Dravidian; they speak a Dravidian language closely allied to Canarese and according to their traditions they came from the Karnatic. The Mal-Paharias of the Rajmahal Hills are closely allied to the Oraon."

I have quoted Dr. Haddon at length as I shall refer to this passage subsequently. From the foregoing, it appears that Dr. Haddon takes the Dravidian speaking Oraons as belonging to the same stock as the Kolarians, though he admits that there is a remarkable difference noticeable which makes it possible to distinguish the Mundas from the Dravidian speaking tribes from the south. Dr. Haddon explains this by referring to the Asura tradition of the Mundas. The Asuras were believed to be a primitive leucoderm people who spoke an early form of Sanskrit or allied language and who probably absorbed an indigenous Melanoderm race (the Nishada of ancient Sanskrit literature) and developed a civilization of their own. The Aryans conquered the Asuras and a section of the latter retreated to Chota-Nagpur and were finally overpowered and absorbed by intrusive short-statured Pre-Dravidian hordes coming from the south.

Col. Dalton has referred to greater physical beauty of the Hos and the Mundas and ascribed this to a considerable admixture of Aryan blood. About the Hos of Singbhum, Col. Dalton wrote,[2] "The Hos of Singbhum and

[1] *Races of Man*, by A. C. Haddon.

[2] *Descriptive Ethnology of Bengal*, by Col. Dalton.

M represents Metre.
mm „ millimetre.

the Mundaris of the southern Pergannah of Lohardaga District are physically a much finer people than the Bhumij, the Sonthals or any other of the Kolarians.....the males average five feet five or six inches in height, the women five feet two... Many have high noses and oval faces and young girls are sometimes met with who have delicate and regular features, finely chiselled straight noses, and perfectly formed mouths and chins. The eyes however are seldom so large, so bright and gazelle-like as those of pure Hindu maidens, but I have met strongly marked Mongolian features and some are dark and coarse as the Sonthals."

Thus, the following relevant questions regarding the Austric-speaking tribes suggest themselves. (1) Whether the Austric-speaking tribes in India or more particularly the Munda-speaking groups represent the same racial type? (2) Is there any racial difference between the Munda and the Dravidian speaking groups? (3) Are the Mundas and Hos more variable than the Sonthals and the Bhumij? These questions I would attempt to answer from an analysis of the two new series of anthropometric measurements of Hos and Saoras and by a comparison of the statistical constants with those of other series available.

Previous Material.

Anthropometric measurements in India were first systematically taken by Sir Herbert Risley in 1891.[3] The difficulties of securing the services of trained anthropologists in those days were indeed great and the technique also was not sufficiently developed, so that doubts have been freely expressed by later workers about the reliability of the data and the methods of analysis used by him. The more recent development of statistical analysis has made it possible to test the reliability or otherwise of anthropometric data, and conclusions arrived at on the basis of statistical analysis in earlier days need be revised. Many of Risley's conclusions have been challenged by later workers and with sufficient reason too. Dr. Hutton points out in his preface to the ethnographical volume of the *Census of India, 1931*, "Risley's conception of India as isolated from the rest of Asia and inhabited entirely by barbarous tribes until the Aryan invasion of *c.* 1500 B.C. already impunged, has been proved to be erroneous by the discovery of Mohenjo-Daro. His explanation of brachycephaly in the west of India due to Scythian invasion

[3] Volume on Ethnographic Appendices to the *Census of India*, 1901.

The first number in a bracket indicates the number of series, the second, the number of individuals in all the series taken together. The North Indian averages were worked out by Prof. P. C. Mahalanobis.

in historic times, has been justifiably attacked on the score that the population so introduced was never so numerous enough to make a complete and permanent change in the somatic characters of the population." Similar objections have been taken against his hypothesis on the Mongolo-Dravidian origin of the Bengalees.

Prof. P. C. Mahalanobis has analysed the anthropometric data published by Risley (*Sankhya*, Vol. I, Pt. 1) and has found a number of more or less serious mistakes in the calculation of average values and individual measurements and comes to the conclusion that his (Risley's) primary data of individual measurements can be used with safety especially after applying the corrections discussed by him. Recently at the Galton Laboratory, University of London, I worked out the means and standard deviations of some of Risley's series and I found that further checking was needed to make the data absolutely reliable. But however reliable the actual measurements may be from the statistical point of view, the fact that Sir Herbert Risley had selected his subjects for measurements has certainly rendered the data of dubious value. Most of the measurements were taken by his assistants and his share in the collection of data lay in 'teaching the measurers, the use of the instruments, in exercising a general control over the work and in supplying them with detailed printed instructions, regarding the technique of the measurements'. The actual instructions issued by Risley is given below: "In selecting subjects only adults between the ages of 25 and 45 should be taken. Accurate determination of age being of course impossible, those persons must be rejected who are obviously not fully grown or who appear to be over 45, deformed persons, dwarfs, cripples and men who have suffered from any disease affecting the form of the nose. In measuring the higher castes, it is as well also to reject persons of very black complexion and with very broad and depressed noses as in lower castes, men of very fair complexion and high caste type of feature should be rejected. The object is to determine the standard type of each caste and for this purpose individuals of clearly exceptional feature should be excluded." Exception has rightly been taken to the latter portion of the instructions. The search for the standard type has naturally led to a selection of the subjects, and it is difficult to say how far these instructions were carried out by his assistants, but it appears that the selection has had significant effect on the calculated values as the standard deviations of Risley's measurements tend in most cases to be lower than values for corresponding characters in groups measured by other anthropologists.

The following part of a table of average variabilities given by Dr. G. M. Morant in his paper on "An Attempt to Estimate the Relative Variabilities

of Various Populations" in *Zeitscrift fur Rassen Kunde*, 1935, Band II, Heft 3, will illustrate this point. The Indian standard deviations are seen to be peculiarly small in the case of the three nasal measurements and the bizygomatic breadth, but it will be shown below that the same relation is not found for other, and unselected Indian series.

	Central Asiatic	North Indian	Norwegian	Macedonian
Head Length	6·25 (21 : 916)	6·30 (35 : 3500)	6·48 (20 : 11770)	6·61 (6 : 955)
Head Breadth	5·41 (21 : 916)	5·00 (35 : 3500)	5·42 (20 : 11764)	5·81 (6 : 955)
Cep. Index	3·71 (21 : 916)	3·36 (35 : 3500)	3·24 (20 : 11761)	3·73 (6 : 955)
Nasal Height	3·86 (21 : 917)	2·88 (35 : 3500)	..	4·28 (6 : 955)
Nasal Breadth	2·98 (21 : 917)	2·51 (35 : 3500)	..	3·30 (6 : 955)
Nasal Index	8·21 (21 : 917)	6·86 (35 : 3500)	..	8·27 (6 : 955)
Bizygo Breadth	6·05 (21 : 916)	4·50 (35 : 3500)	5·28 (20 : 11766)	5·88 (6 : 955)

Since Risley, anthropometric measurements of a number of tribes and castes in India have been undertaken by anthropologists, both Indian and foreign, but unfortunately the data collected by them are seldom comparable as there has been no agreement regarding the number of characters of a particular sample measured or the technique of measurement. In some cases however, the number is obviously too small. Besides, there is in all cases, a lack of estimates of personal equation involved. Again, individual measurements have not been published which precludes the possibility of re-examining them in the light of recent advances in the technique of statistical analysis.

Recently in connection with the Census of India, 1931, Dr. B. S. Guha of the Zoological Survey of India has published the results of his analysis of the measurements of 34 'racial' groups of which 14 were Brahmins, 16 belonging to various Hindu castes and 4 tribal.[4] The total number of persons measured by him were 2,511. With the exception of 171 Nicobarese all these subjects were measured by Dr. Guha himself. After Sir Herbert Risley's, Dr. Guha's work should rank as the most important contribution to our knowledge of the somatology of the Indian races in recent years. In some respects, Dr. Guha's work is unique. The statistical analysis of the data is based on 29 characters which is the largest yet attempted by any anthropologist for so large a population. Besides he has computed 627 crude

[4] *Census of India*, 1931, Vol. 1, Pt. III (Ethnographical).

coefficients of racial likeness of which 520 are based on his own measurements, a number, the largest yet calculated on the living.

Dr. Guha claims, that, as all the measurements were taken by himself, the influence of personal equation on the values for the living subjects has been very much smaller than on those based on the cranial materials of several independent investigators. No evidence, such as data which would provide estimate of personal equation in support of this assumption is, however, provided. Measurements on the skull are bound to be more accurate even if different persons trained in the techniques take them, due to the nature of the material; the difference of pressure to take one aspect of it on the living, is reduced to insignificance on bones.[5] At any rate there can be no doubt that cranial measurements recorded by different workers can be compared with far greater accuracy than measurements of the living taken by different workers. Even measurements on the living taken by different anthropologists following the same technique can seldom be compared safely in the case of all the usual characters. There is an urgent need for an investigation based on repeated measurements of the same individuals which will give reliable estimates of the personal equations of single workers in measuring series of living people, and of the accuracy with which comparisons can be made between such data collected by different workers. The future of physical anthropology, I should think, largely depends on the development and should I say, perfection of a method which will largely eliminate any significant difference in the values of the data collected from samples of the same population by different workers.

Dr. Guha has compared his own data with those of other workers in a few cases. For example, he compares his own series with one of 92 Burushaskhis measured in Hunza by the late Prof. R. B. Dixon of Harvard which is yet unpublished. The reduced coefficient of racial likeness between the Upper Chitral (Guha) and Hunza (Dixon) series is given as $39 \cdot 67 \pm \cdot 38$ which

[5] Prof. R. A. Fisher, in his article on "The Coefficient of Racial Likeness and the Future of Craniometry," *J. R. A. I.*, 1936, while admitting that skulls possess a real though slight advantage over living heads in the accuracy with which they can be measured, points out that this advantage is very unimportant, "since the variation produced by fleshy tissues are small compared with the metrical differences between individuals, with the consequence that the average of any measurement taken on the living, from a sample of fifty or a hundred has practically the same precision as that of the corresponding measurement of the skulls". The vagueness of some of the landmarks in cephalometry, for instance, and the scope for pressure in the measurement of certain somatic characters make anthropometry less reliable than craniometry and examples are not lacking when two investigators taking measurements on two samples of the same population, following the same technique, have come to very different results.

indicates marked divergence. Between the Upper Chitral (Mustuji) and Hunza series measured by Sir Aurel Stein and calculated by Dr. G. M. Morant, a reduced coefficient of $2 \cdot 1 \pm \cdot 78$ is found, showing that the two populations are not differentiated by the series. Again, Dr. Guha has compared his data on some tribal groups measured by him, with some hitherto unpublished data by the late Mr. P. C. Basu on the Mundas and the Oraons of Chota-Nagpur. From a comparison of the latter series with those of his own, Guha finds that the Oraons do not differ from the Mundas, a fact which goes against recent historical evidence. The reduced coefficient of racial likeness between the Oraons and the Mundas is 1·79 while the same between the Mundas and the Bhils apparently belonging to the same ethnic stock and speaking dialects traceable to the Austric family of languages, is 29·61. On the other hand, on the basis of his Text-Fig. 5, p. XIX, *Census Reports*, 1931, Vol. I, Pt. III, I should think that his own data regarding the interrelation of the Bhils with the South Indian tribes gives a more accurate estimate of racial difference, which I find corroborated from my material. He gives the reduced coefficient of racial likeness between the Oraons and the Bhils as 39·54, a very high figure, indicating probably a more real divergence than Dr. Guha is prepared to admit perhaps, but I should think very much expected. If Dr. Guha had measured the Mundas and the Oraons himself, as he has done the other groups, he would have perhaps come to a different conclusion. Although he admits the probability that the samples measured by Mr. P. C. Basu may not be representative as the Oraons living in the neighbourhood of the Ranchi District which were measured by Mr. Basu were evidently a mixed group, his conclusion regarding the ethnic composition of the tribal groups derives not a little support from the data provided by Basu. Thus he sums up the racial elements in the tribal people of India as follows, "……though we have no direct evidence of the Negrito race in the old skeletal remains of India the skull of a victim of human sacrifice found in a cairn at Jewurgi is remarkably Negroid. The Australoid type found so largely in the present-day Indian aboriginese is however abundantly represented both in the South Indian and Chota-Nagpur sites, and judging from the description given by the Vedic Aryans there seems hardly any doubt that they were the Nishadas who formerly as to-day occupied the hills and forests of India. Various names have been given to this race such as Nisadic, the generic name given to them by the Vedic Aryans and resuscitated by Mr. Chanda, and which should henceforth be used to designate the non-negritoid Indian aboriginese."

There is no adequate craniological material to demonstrate that there was ever a negrito population in India. Guha talks of Negrito groups judged

as such from his measurements of living series. Besides, the evidence of mythology or of scriptures cannot be accepted as conclusive particularly where such question as race origins is concerned. A cultural stage represented by the Nishadas, *viz.*, hunting should not be interpreted as a racial category even if it comprises many groups ethnically alike. We are looking forward to the publication of Dr. Guha's data of individual measurements without which this question cannot be thoroughly discussed.

To come to Dr. Guha's Nishadic hypothesis, it appears that he does hardly recognise any difference between the tribes of central and northern India and those of the south. In other words, except for his Negrito hypothesis, he has partially revived Risley's 'Dravidian theory'. I therefore propose to discuss this hypothesis in the light of the data I possess and those I could get from Risley and other workers. I shall also attempt to estimate the value of Risley's data for comparative purposes. If we find that the data of Risley with all the limitations due to selection, do not show any very significant difference compared to data on similar ethnic groups collected by other workers, it may be profitable to extend this comparison to Dr. Guha's material. I have chosen two series of Risley's measurements, *viz.*, 100 ♂ Mundas and 100 ♂ Bhumij, a series of 165 Hos measured by Mr. A. N. Chatterjee of the Calcutta University, and a few series of high castes and tribal groups measured by Dr. Guha for purposes of comparison with the two series of mine, *viz.*, the Hos and the Saoras.

The technique used in obtaining the measurements of the Hos and the Saoras, was the same, as that followed by Dr. Guha (*i.e.*, it is that of the International Agreement of Monaco) and therefore comparable to the series of Dr. Guha for the following absolute measurements: (1) Stature, (2) Maximum Head Length, (3) Maximum Head Breadth, (4) Nasal Height (or length), (5) Nasal Width, (6) Maximum Bizygomatic Breadth, (7) Bigonial Breadth. The difficulty of locating Nasion on living head cannot but influence the nasal measurements and when considering these data, this point should not be forgotten. Risley's technique except for the nasal measurements may be supposed to be the same and Mr. Chatterjee has, I am told, used the Monaco technique and similar instruments. Although the characters for comparison are not many and conclusions based on them may not be very accurate, yet it will certainly indicate the possibility of making accurate comparisons of data gathered by different workers working on the same or very similar techniques and using the same kind of instruments.

The selection of the different series for comparison mentioned already, *viz.*, (1) 165 Hos of Mr. A. N. Chatterjee, (2) 100 ♂ Mundas and (3) 100 ♂

Bhumij of Risley, (4) 50♂ Brahmins, (5) 100♂ Kayasthas, (6) 81♂ Khasis of Dr. Guha, has been deliberately made, as my purpose is (*a*) to show if my measurements of the Hos agree with those of Mr. Chatterjee, (*b*) if the Hos represent the same population designated as Mundas and Bhumij, (*c*) how far they differ from the Mongolid tribe, the Khasis of Assam, (*d*) how the Brahmins and the Kayasthas of Bengal who are also their neighbours in and around their settlements differ from them and, lastly (*e*) to show the relationship between the Hos and the Saoras, and the Saoras and other groups mentioned in this connection.

I may however add, that I have not selected my subjects and the Hos and the Saoras I have measured represent all ages from 22 to 48 and all parts of the country where they live. The Hos all belong to the Kolhan Government Estate and the Saoras live in the jungles of Udaygiri in the Ganjam Agency tracts, Madras Presidency. The latter mostly live by crude cultivation known as Podu which is the same as the Jhum cultivation of Assam and the Dahiya of Northern India. A plot of forest land is cleared of trees, the stumps are set fire to, and all kinds of seeds are simultaneously thrown in on the ashes. They dance their native dances, sacrifice fowls or pigs and pray to the gods presiding over crops and rains which ensure a bumper crop, sometimes two-fold, sometimes four-fold but sometimes none at all.

I have calculated the means and standard deviations and coefficients of variations for Risley's series as far as available for characters I recorded for purposes of comparison. Guha gives these constants and his values are quoted.

As regards the reliability of my series, it will be useful first of all to compare my data on the Hos with similar data collected by another investigator Mr. A. N. Chatterjee. The latter[6] has published the results of his analysis of the measurements of 208 Hos (two groups of 165 and 43) based on four measurements and three indices. I can only compare my data with those for his three absolute measurements and two indices. He has given nasal index but not the nasal height and width and as there is a confusion in anthropological literature about these measurements, I do not know whether his value for nasal index will be of any great use for our purpose, but at any rate it will give us some idea about the nature of the material we are dealing with. There is another important point on which Mr. Chatterjee has remained silent and that is, he has not mentioned whether his subjects

[6] *The Hos of Seraikhela*, by A. N. Chatterjee and T. C. Das. Calcutta University Press.

were all males or there were females included in the series. In the absence of any statement on this point, I take it that the measurements were for males only, and this appears to be confirmed by a comparison of his mean stature with mine. The analysis of his data shows some mistakes in the statistical part, and I had to revise some of the constants and their probable errors. The conclusions he has arrived at on the basis of his data are not possible to check completely as he has not given individual measurements.

Mr. Chatterjee classifies the Hos into 'six fundamental types' as he calls them, on the basis of his data, *viz.*, (1) Dolichocephalic-Hypsicephalic-Leptorhine, (2) Dolichocephalic-Hypsicephalic-Platyrhine, (3) Dolichocephalic-Chamæcephalic-Platyrhine, (4) Dolichocephalic-Chamæcephalic-Leptorhine, (5) Brachycephalic-Hypsicephalic-Leptorhine, (6) Brachycephalic-Hypsicephalic-Platyrhine, and comes to the following hypothesis about the racial composition of the Hos.

"The underlying predominant stratum seems to be Proto-Negroid with indications of a faint strain of Proto-Australoid admixture. The Negrito sub-type of the Palæ-Alpine group seems to have played some part in the formation of the type. The chronological relation and the extent of admixture between the Proto-Negroids and the Palæ-Alpines we are not in a position to indicate from the physical data alone. The Caspian element seems to have played an important part in the evolution of the type and appears to have been longer in contact with the Proto-Negroids than the Alpines". This illustrates Dr. G. M. Morant's statement that "the confidence with which anthropological theories are propounded is often found inversely proportional to the amount of material to support them".[7] Owing to the considerable variability exhibited by all unselected populations, it is evident that if Mr. Chatterjee had cared to analyse the measurements of any supposed homogeneous group he has cited in his paper, he would certainly have got all the 'fundamental types' he has found among the Hos and probably more.

A Comparison of the Two Ho Series.

100 ♂ *Hos* (Majumdar)..(*A*) *and* 165 ♂ *Hos* (Chatterjee)..(*B*)

The means and standard deviations of these series are given in Tables I and II respectively along with those of the other series. In comparing the constants, Table III, a difference greater than 3·5 times its probable error will be considered significant. Between the two series A and B,

[7] Article on "A contribution to the Physical Anthropology of the Swat and Hunza Valleys based on Records collected by Sir Aurel Stein," Foot Note, Page 40, *J. R.A.I.*, 1936.

comparison of the means of five absolute measurements and indices shows a significant difference only in the case of nasal index (4·2). The mean nasal index for B is 82·9 ± ·50 and for A, 79·7 ± ·54. The cephalic index, head length, head breadth and stature show no significant differences. As we have already said that the difference in the nasal measurements is likely to occur owing to the difficulty of applying the Monaco definition of the nasal length and to the question of pressure. Hence it would be quite unsafe to assume that the small difference between the mean nasal indices observed, though statistically significant, really indicates that the samples do not represent the same population. Besides, the individual measurements have not been given by Mr. Chatterjee and this difference in the means of the nasal index in the two series may be due to a mistake in calculating average values, a suspicion which naturally arises in view of mistakes in calculation and in the values of the statistical constants found in the paper. He has compared the values for 165 Hos with those of a second group of 43 Hos but curiously enough, he has not mentioned the nasal index or nasal measurements in this connection.

A comparison of the standard deviations reveals no significant differences between these two series. For four of the five characters, the standard deviations for the B series exceed those for A; but no importance can be attached to this relation as all the differences are quite insignificant. However, the Hos of Seraikhela whom Mr. Chatterjee has measured are known to be a mixed group. They have lost their language and are more Hinduised than their brethren of the Kolhan. Hence a higher variability for them, if demonstrated, would not be unexpected. Although the number of characters on which this comparison is made are small and that any conclusion based on such evidence connot be accepted as final, it may however be provisionally concluded that the two samples A and B do not show any marked divergence which cannot be attributed to a chance selection, in other words, they appear to represent the same population as far as can be told, if we suppose that no importance should be attached to the difference between the means of the nasal indices recorded by the two observers.

Comparison of the Ho Series (Majumdar) *with* 100 ♂ *Mundas and* 100 ♂ *Bhumij* (Risley).

The Bhumij and the Mundas are two neighbouring groups occupying the same part of the country and believed to be of the same racial stock. The social divisions within these groups and also among the Hos are based on totemic principles and the same clan names are even to-day traceable though the Bhumij have been Hinduised to a much greater extent than

either the Mundas or the Hos. As a matter of fact, the Bhumij are taken as an example of a tribe which has transformed itself into a caste which illustrates that there has been a transition from the tribal stage to that of the caste with Hinduisation. All these tribes speak the same language and share more or less the same culture pattern.

A comparison of the means of the measurements of these three groups shows that quite marked differences do exist and we have to account for these differences if we are to accept the data as fairly reliable. The Hos differ from the Mundas in stature (3·8) ; N.L. or N.H. (13·0) ; N.B. (6·1) ; N. Index (14·3), in mean measurements. The mean stature for the Hos (in millimetres) is $1609·7 \pm 3·9$ and for the Mundas $1589·0 \pm 3·8$. The Hos differ from the Bhumij in N.L. or N.H. (5·4), N.B. (6·5), N.I. (9·6). Thus if we exclude the nasal measurements, the only significant difference between the Hos and the Mundas is in stature, while between the Hos and the Bhumij there is no evidence of differentiation. But this difference in stature is very small and only just significant, while all the differences between the nasal measurements are markedly significant. It may be noted too, that the Munda mean is not significantly different from Chatterjee's. Besides a difference of 1 cm. in the mean stature may possibly be due to a difference in the way the measurements are taken. Ignoring stature, our Ho series is only distinguished from the other two by its nasal measurements, and this difference was to be expected.

A comparison of the standard deviations for the three series reveals fewer significant differences. The value for the cephalic index for my Ho series is significantly greater than those for the Munda and Bhumij, and Chatterjee's Ho series differ still more significantly from them in the same respect. It may be noted that for seven of the eight characters the Ho (Majumdar) variability is greater than the Munda, but the absolute differences between the corresponding constants are all small except in the case of the cephalic index. All the series exhibit approximately the same order of variability, as is usually found in such comparisons.

It is the nasal measurements of Risley which are of doubtful value and yet all his hypotheses of racial origins of the Indian peoples are largely based on the nasal index. Risley's definitions of the nasal measurements differ from those of the International Agreement and some of the significant differences found may be due entirely to this fact. It may be noticed, however, that both the Munda and Bhumij series are Risley's and their means differ significantly in the case of the nasal length (? height) and nasal index. There is still a possibility that this result may be misleading, since the nasal length from the most depressed point on the nasal bridge is such

a vaguely defined measurement that two observers taking it on the same series are quite likely to obtain appreciably different means. We do not know whether the Munda and Bhumij series were measured by the same person or by two of Risley's assistants.

Thus as we have found in the case of the two Ho series, there does not appear any clearly significant difference between the three types, *viz.*, the Hos, the Bhumij and the Mundas, except for the nasal measurements, and I shall not be wrong to assume that the groups represent populations having the same or very similar origins. Further, this shows that measurements taken by different workers on samples representing either different branches of the same race or different samples of the same or different populations, are comparable for the usual characters, if the techniques of measurement are uniform. The effect of selection on the data can be statistically estimated. It appears that comparison of Risley's data for several of characters given by him can profitably be employed to check the measuremeants of other workers though allowance must be made for the selection of his material.

Before I proceed to the next comparison, it would be interesting to note that Dr. A. C. Haddon gives in his *Races of Man* (already quoted) the stature of the Hos as 1680·0 mm. This makes the short statured Hos resemble the Brahmins of Bengal (Guha), whose mean stature is given as 1680·30 ± 5·14. Mr. Chatterjee's value for stature of the Hos is 1600·0 ± 2·9 and the corresponding value in my series is 1609·7 ± 3·9. Col. Dalton gives the stature of the Hos at 5ft. 5 to 6 inches, which expressed in mm. is 1651·0 to 1676·4. This also is significantly different from the values obtained by Risley, Chatterjee and myself. Difference in technique in stature cannot account for this large difference. Nor is it likely that this difference of 8 cm. in mean stature can be attributed to a decrease in stature among the Hos during the last 3 to 4 decades. Risley's mean stature for cognate tribes are Mundas 1589·0 ± 3·8, Bhumij 1592·1 ± 3·9. It appears that Dr. Haddon has taken his figures from Col. Dalton (1676·4 mm.) which he put down as 168 cm. after calculating to the nearest decimal place.

Comparison of the Saoras (Majumdar) *with the Hos* (Majumdar) *and with the Mundas and Bhumij* (Risley).

The three series treated so far, the Hos, Munda and Bhumij are believed from historical and cultural evidence to have had the same or very similar origins and the close similarity observed between their physical types accords with this hypothesis. They are believed to belong to an entirely different stock from that represented by the Saoras and it will be seen that

the measurements available confirm this belief. In the case of the Hos and the Saoras comparisons can be made for 12 characters and the question of differences in the technique of measurements does not arise as I measured both the series. The means are found to differ significantly in 7 of the 12 comparisons and with very marked significance in the case of the nasal length and bizygomatic breadth (see Table III). Comparisons of the Saoras with Risley's two series can only be made for 8 characters, and it has been shown that it is fairly safe to assume that for 5 of these the influence of personal equation can be neglected, but that for the other three (*viz.*, the three nasal measurements) it must be taken into account. The means for the Saoras and Mundas show three significant differences ; two of these are for nasal measurements, and the third which indicates marked significance is for the bizygomatic breadth. The means for the Saoras and Bhumij show five of the eight differences significant ; two of these are for nasal measurements and the most markedly significant difference is for the bizygomatic breadth. It may be noted that of the eight characters for which comparison between Risley's measurements and mine is possible, four show significant differences between my Saora and Ho series. It is clear that the Saora is markedly distinguished from the other three which resemble one another closely. It has a slightly smaller stature and a markedly narrower face. It is probable, also, that it has a markedly higher nasal index, remembering that Risley's nasal measurements are likely to give considerable higher values of the index than those obtained in accordance with the definitions of the International Agreement. There is a distinct suggestion that the Munda type diverges slightly from those of the Ho and the Bhumij in the direction of the Saora type since it has a lesser stature and bizygomatic breadth and apparently a higher nasal index than those two. But no importance should be attached to this point unless it can be confirmed by the comparison of longer series and a larger number of characters. The only conclusion which it is safe to draw now is that the Ho, Bhumij and Munda populations are closely allied and that the Saora type differs clearly from the group to which they belong. It is of interest to note that the cephalic indices for all four types are almost identical, and it is clear that in India the lack of distinction between the means of series for this character is not sufficient evidence of affinity, a considerable number of characters must be available before there can be any hope of reaching reliable conclusions, and it must be admitted that the largest number which it is possible to use in comparisons in this paper (*viz.*, 12 for my series) is really inadequate for the purpose in view.

The measures of variability show far fewer significant differences. None whatever are found for the Saora series, on the one hand, and the

Munda and the Bhumij, on the other, and there is only one for the Ho and the Saora, the latter having the significantly greater standard deviation for the bizygomatic breadth. The variabilities of all four series are so close that there can be no justification for attempting to interpret differences between them in this respect. Such a conclusion does not accord with expectation, as it has been suspected that the Hos and the Bhumij have been mixed with other peoples (*cf.* Haddon and Dalton).

Comparison of the Hos and the Saoras with 50 ♂ *Brahmins,* 100 ♂ *Kayasthas, both from Bengal and* 81 ♂ *Khasis from Assam all being Guha's Series.*

A glance at Tables I, II and III will explain the racial distance of the Hos and the Saoras from both the high caste groups, *viz.*, Brahmins and Kayasthas and from the tribal group represented by the Khasis. Of the 10 characters, absolute and indical, compared, significant differences exist between the Hos, the Saoras and the caste groups. The Hos differ from the Brahmins in stature 10·9, N.I. 14·7, H.B. 15·1, N.L. or N.H. 13·2, N.B. 6·0, Bg. 6·1 and C.I. 4·0, from the Kayasthas, in stature 11·1, H.B. 24·1, N.I. 17·6, Bz. 6·6, Bg. 8·4, N.L. 18·4, N.B. 6·1 and C.I. 16·2. The high values of these differences must be interpreted to mean a racial difference between the Hos and the caste groups. Similarly the Saoras differ significantly from the Brahmins and the Kayasthas in 8 characters out of 10, showing a clear divergence in racial composition. Between the Hos and the Khasis, significant differences exist in stature, head-length, facial length, bigonial breadth, bizygomatic breadth and cephalic index. The Saoras differ from the Khasis substantially in most of the characters. The Hos and the Saoras on the basis of this comparison must be taken to belong to different stocks than that of the Khasis which is a Mongoloid tribe of Assam. Thus it is probable that the Mongolian element had little to do with the racial make-up of the Hos, although here and there certain Mongoloid traits have been discovered by Col. Dalton and later on mentioned by Dr. A. C. Haddon. The general physical appearance of the tribes of Chota-Nagpur do not suggest any Mongolian infusion either. A few stray cases may be explained by frequent alliances of tribal women with men who live in the vicinity of tribal villages, in markets and fairs all over the area among whom there are people of Mongoloid extraction but to ascribe these cases to a general miscegenation with Mongoloid stock is hard to maintain.

TABLE I.

Means for a Number of Living Series.

	Hos. 100 ♂ (Majumdar)	Hos. 165 ♂ (Chatterjee)	Mundas 100 ♂ (Risley)	Bhumij 100 ♂ (Risley)	Saoras 100 ♂ (Majumdar)	Kayasthas 100 ♂ (Guha)	Brahmins 50 ♂ (Guha)	Khasis 81 ♂ (Guha)	Remarks
Stature ..	1609·7 ± 3·9	1600·0 ± 2·9	1589·0 ± 3·8	1592·1 ± 3·9	1572·8 ± 3·7	1670·7 ± 3·9	1680·3 ± 5·1	1569·1 ± 4·7	Calculated to the nearest decimal place
Head Length ..	184·4 ± ·41	185·0 ± ·35	185·9 ± ·40	185·8 ± ·38	184·7 ± ·38	185·3 ± ·43	186·4 ± ·58	186·9 ± ·42	
Head Breadth ..	138·5 ± ·28	138·5 ± ·24	138·6 ± ·26	139·6 ± ·31	137·5 ± ·33	149·6 ± ·37	147·0 ± ·49	144·5 ± ·40	
Nasal Height ..	48·7 ± ·24	..	44·7 ± ·20	46·7 ± ·28	45·0 ± ·24	54·6 ± ·21	54·2 ± ·34	49·1 ± ·29	
Nasal Width ..	38·7 ± ·20	..	40·7 ± ·27	40·4 ± ·16	38·2 ± ·17	37·1 ± ·17	36·6 ± ·29	37·9 ± ·20	
Facial Length	121·2 ± ·47	..	..	..	120·0 ± ·50	120·1 ± ·37	121·7 ± ·57	113·1 ± ·44	
Bizygomatic Breadth ..	131·6 ± ·29	..	130·7 ± ·29	131·4 ± ·31	125·9 ± ·39	134·7 ± ·37	132·8 ± ·48	133·8 ± ·41	
Bigonial ..	97·2 ± ·33	..	..	..	95·1 ± ·36	101·6 ± ·40	101·2 ± ·56	106·1 ± ·64	
C.I. ..	75·1 ± ·23	75·0 ± ·19	74·5 ± ·16	75·1 ± ·18	74·5 ± ·28	80·8 ± ·26	78·9 ± ·33	77·3 ± ·20	
N.I. ..	79·7 ± ·54	82·9 ± ·50	90·6 ± ·53	86·6 ± ·46	85·2 ± ·47	68·1 ± ·38	67·7 ± ·62	77·4 ± ·52	
F.I. ..	92·1 ± ·28	..	..	..	95·3 ± ·40	89·3 ± ·36	91·7 ± ·48	84·5 ± ·34	
Bz-Bg-I. ..	73·9 ± ·26	..	..	..	75·6 ± ·24	..	..	..	

C.I. = Cephalic Index.
N.I. = Nasal Index.
F.I. = Facial Index.
Bz-Bg-I. = Bizygomatic Biognial Index.

TABLE II.

Standard Deviations.

	Hos. 100 ♂ (Majumdar)	Hos. 165 ♂ (Chatterji)	Mundas 100 ♂ (Risley)	Bhumij 100 ♂ (Risley)	Saoras 100 ♂ (Majumdar))	Kayasthas 100 ♂ (Guha)	Brahmins 50 ♂ (Guha)	Khasis 81 ♂ (Guha)
Stature ..	57·3 ± 2·7	56·0 ± 2·1	56·7 ± 2·7	57·9 ± 2·8	55·2 ± 2·6	57·0 ± 2·7	53·9 ± 3·6	62·3 ± 3·3
H.L.	6·20 ± ·30	6·58 ± ·24	6·01 ± ·29	5·63 ± ·27	5·66 ± ·27	6·32 ± ·30	6·04 ± ·41	5·57 ± ·30
H.B.	4·23 ± ·20	4·65 ± ·13	3·90 ± ·19	4·63 ± ·22	4·92 ± ·23	5·43 ± ·26	5·16 ± ·35	5·26 ± ·28
N.L.	3·63 ± ·17	..	3·02 ± ·14	2·65 ± ·13	3·61 ± ·17	3·05 ± ·15	3·52 ± ·24	3·89 ± ·21
N.B.	2·99 ± ·14	..	2·41 ± ·11	2·42 ± ·11	2·52 ± ·12	2·46 ± ·12	3·05 ± ·21	2·74 ± ·14
F.L.	6·99 ± ·33	..	..	..	7·43 ± ·35	5·48 ± ·26	6·00 ± ·40	5·81 ± ·31
Bz.	4·25 ± ·20	..	4·38 ± ·21	4·54 ± ·22	5·88 ± ·28	5·52 ± ·26	5·03 ± ·34	5·53 ± ·29
Bg.	4·95 ± ·24	..	..	..	5·27 ± ·25	5·89 ± ·28	5·91 ± ·40	8·62 ± ·46
C.I.	3·49 ± ·17	3·71 ± ·14	2·44 ± ·12	2·61 ± ·12	2·77 ± ·13	3·89 ± ·19	3·42 ± ·23	2·70 ± ·14
N.I.	8·08 ± ·38	9·50 ± ·35	7·86 ± ·37	6·87 ± ·33	7·04 ± ·34	5·70 ± ·27	6·48 ± ·44	6·94 ± ·37
F.I.	4·29 ± ·20	..	..	..	59·8 ± ·28	5·39 ± ·26	5·02 ± ·34	4·49 ± ·24
Bz-Bg-I ..	3·92 ± ·19	..	..	..	3·68 ± ·17	..	..	..

Abbreviations :—
H.L.—Head Length.
H.B.—Head Breadth.
N.L.—Nasal Height or Length.
N.B.—Nasal Breadth.
F.L.—Facial Length.
B.Z.—Bizygomatic Breadth.
B.G.—Bigonial Breadth.
Measurements are in Millimetres.

TABLE III.

Comparison of Differences of Means and Standard Deviations in terms of their Probable Errors, Values above 3·5 are given.

	Number of Characters compared	Characters and their Means	Characters and their standord deviatians
Hos (Majumdar) and Hos (Chatterjee) ..	5	N.I. 4·2	..
Hos (Majumdar) and Mundas (Risley) ..	8	Stature 3·8, N.L. 13·0, N.B. 6·1, N.I. 14·3	C.I. 5·0
Hos (Majumdar) and Bhumij (Risley) ..	8	N.L. 5·4, N.B. 6·5, N.I. 9·6	C.I. 4·2
Hos (Majumdar) and Saoras (Majumdar) ..	12	Stature 7·4, N.L. 11·0, Bz. 11·6, N.I. 7·6, Bg. 4·3, F.I. 6·7, Bz-Bg-I. 4·8	Bz. 4·8
Bhumij (Risley) and Saoras (Majumdar) ..	8	Stature 3·6, H.B. 4·7, N.L. 4·6, N.B. 9·1, Bz. 11·0	..
Mundas (Risley) and Saoras (Majumdar) ..	8	N.B. 7·8, Bz. 10·0, N.I. 7·6	..
Brahmins (Guha) and Kayasthas (Guha) ..	10	H.B. 4·3, C.I. 4·5	..
Brahmins (Guha) and Hos (Majumdar) ..	10	Stature 10·9, N.I. 14·7, H.B. 15·1, N.L. 13·2, Bg. 6·1, N.B. 6·0, C.I. 4·0	F.L. 3·6, H.B. 3·7
Hos (Majumdar) and Khasis (Guha) ..	10	Stature 6·7, H.L. 4·3, Bg. 12·3, F.L. 12·6, Bz. 4·4, C.I. 7·3	Bg. 7·1, C.I. 3·6
Saoras (Majumdar) and Khasis (Guha) ..	10	F.L. 10·3, H.L. 3·9, H.B. 17·1, N.I. 11·1, Bz. 14·0, Bg. 15·0, N.L. 10·9, C.I. 8·4	..
Brahmins (Guha) and Saoras (Majumdar) ..	10	Stature 17·0, N.I. 18·6, H.B. 16·0, Bz. 11·1, Bg. 9·2, N.L. 22·1 N.B. 4·7, C.I. 10·4	..
Brahmins (Guha) and Khasis (Guha) ..	10	Stature 16·0, F.L. 11·9, H.B. 3·9, N.I. 12·0, Bg. 5·8, N.L. 11·4, N.B. 3·7, C.I. 4·2	Bg. 4·5
Kayasthas (Guha) and Hos (Majumdar) ..	10	Stature 11·1, H.B. 24·1, N.I. 17·6, Bz. 6·6, Bg. 8·4, N.L. 18·4, N.B. 6·1, C.I. 16·2	N.I. 5·1
Kayasthas (Guha) and Khasis (Guha) ..	10	Stature 16·8, F.L. 12·3, H.B. 9.4, N.I. 14·5, Bg. 6·0, N.L. 15·3, C.I. 10·7	Bg. 5·3, C.I. 5·0
Kayasthas (Guha) and Saoras (Majumdar) ..	10	Stature 18·3, N.I. 28·5, H.B. 24·7, Bz. 16·3, Bg. 12·0, N.L. 30·0, N.B. 4·6, C.I. 16·8	..

TABLE IV.

Coefficients of Variation for the Groups mentioned in the Preceeding Tables.

Coefficients of Variation.

	100 ♂ Hos. (M)	100 ♂ Mundas (R)	100 ♂ Bhumij (R)	100 ♂ (Saoras M)	165 ♂ Hos. (C)	50 ♂ Khasis (G)	100 ♂ Kayasthas	50 ♂ Brahmins (G)
Stature ..	3·6 ± ·17	3·6 ± ·14	3·6 ± ·17	3·5 ± ·17	3·6 ± ·13	3·97 ± ·21	3·43 ± ·16	3·21 ± ·22
H.L. ..	3·4 ± ·16	3·2 ± ·14	3·0 ± ·14	3·1 ± ·15	3·5 ± ·13	3·0 ± ·16	3·47 ± ·16	3·24 ± ·22
H.B. ..	3·0 ± ·14	2·8 ± ·13	3·3 ± ·16	3·6 ± ·14	3·4 ± ·13	3·67 ± ·19	3·63 ± ·17	3·51 ± ·24
N.L. ..	7·4 ± ·35	6·8 ± ·33	7·9 ± ·38	8·0 ± ·38		7·94 ± ·42	5·59 ± ·27	6·49 ± ·44
N.B. ..	7·7 ± ·36	5·9 ± ·28	3·5 ± ·17	6·6 ± ·32		7·12 ± ·38	6·65 ± ·32	8·34 ± ·57
F.L. ..	5·7 ± ·27			6·2 ± ·30		5·13 ± ·27	5·71 ± ·27	6·70 ± ·45
Bz. ..	3·2 ± ·14	3·4 ± ·16	3·4 ± ·16	4·7 ± ·22		4·11 ± ·22	4·10 ± ·20	3·79 ± ·26
Bg. ..	5·1 ± ·24			5·5 ± ·26		8·11 ± ·43	5·80 ± ·28	5·84 ± ·39
I. ..	4·6 ± ·22	3·2 ± ·14	6·0 ± ·29	3·7 ± ·18		3·49 ± ·18	5·55 ± ·27	4·33 ± ·29
N.I. ..	10·0 ± ·48	8·7 ± ·55	8·8 ± ·42	8·3 ± ·40		8·91 ± ·48	8·37 ± ·40	9·57 ± ·65
F.I.	4·7 ± ·22			6·3 ± ·30		5·33 ± ·28	6·03 ± ·29	5·48 ± ·37
Bz-Bg-I. ..	5·3 ± ·26			4·9 ± ·23				

M—Majumdar.
R—Risley.
C—Chatterjee.
G—Guha.

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Conclusion.

The total material dealt with in the paper is not large, and that small series are being used to represent very large populations. It is also less valuable than it should be owing to differences in methods of measurement, and some uncertainty as to whether data collected by different observers are truly comparable even in cases where they followed the same technique. It seems to be safe to assume that certain of Risley's measurements can still be used with profit, and that his means are not affected very markedly owing to the fact that the subjects were selected. Above all the number of characters used is not sufficient to give reliable estimates of racial affinity. Recognising these limitations it appears to be adequately demonstrated that four distinct ethnic groups are represented by the series considered, *viz.*,

(*a*) Saoras (possibly allied to Oraons and others).
(*b*) Hos, Mundas and Bhumij (Austric-speaking).
(*c*) Kayasthas and Brahmins.
(*d*) Khasis.

These four appear to be quite distinct, but it is extremely probable that there are transitional types between some pairs of them, and data for these will be required in order to reveal their ethnic relationships.*

* The individual measurements will be published along with other measurements in my forthcoming publication on the " Ethnology of the Austric-speaking Tribes ".—D.M.

ON THE CULTURE BEHAVIOUR OF A SPECIES OF *ROSELLINIA*.

II. Further Experiments on the Production of Perithecia.

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Introduction.

In an earlier paper (Das Gupta, 1937) an account has been given of the inhibitory effect of certain chemicals on the production of perithecia in a species of *Rosellinia*. It has been shown that the complete absence of perithecia in a standard synthetic medium which consisted of glucose, asparagin, magnesium sulphate, potassium phosphate (K_3PO_4), starch and agar was due to the combined effect of asparagin and potassium phosphate although none of these two chemicals has any inhibitory influence individually. It has been further shown that glucose at any concentration beyond 0·3 per cent. and potassium phosphate at about 0·6 per cent. completely inhibit the formation of perithecia.

The present paper embodies the results of further nutritional work on the problem which was carried out by growing *Rosellinia* in various concentrations of acid and alkali and such chemicals as asparagin, potassium nitrate, etc.

Fungus.—The fungus *Rosellinia* as stated in the previous paper (Das Gupta, 1937) was obtained by Horne and Nitimargi in the course of their investigation into the fungal population in the air of the apple orchard of the East Malling Experimental Station (England) from whom it was obtained by the present author. The fungus was cleaned and cultures derived from a single hyphal tip of uncontaminated mycelium were used throughout the experiment.

Method.—Usual culture method was employed in order to find out the effect of various chemicals and the acidity of the medium on the production of perithecia. Plain agar which proved very suitable for perithecia production was taken as the basal medium, and the chemicals whose effects were to be ascertained were mixed to the agar medium in requisite proportions. The media were autoclaved, poured in sterilized plates and inoculated with *Rosellinia*. To ensure uniformity of growth, the mycelium used for inoculation was always taken from the advancing region of a culture three days

old. The number of perithecia formed in young cultures was counted by putting ink dots on the back or the top of the petri-dish against each perithecium but for older cultures which had been left long enough and had been allowed sufficient time to exhaust all possibilities of further development of fresh perithecia, these were counted by picking perithecia out one after another by means of a needle. It should be borne in mind that the actual number of perithecia formed varies from experiment to experiment even when carried out in the same medium and in identical conditions. The perithecia number of two different experiments is not strictly comparable. All experiments were carried out at 20° C. except where stated otherwise.

The composition of the standard medium which was also used in the course of the experiment, is as follows :

Asparagin 2 gms., glucose 2 gms., magnesium sulphate 0·75 gms., potassium phosphate 1·25 gms., starch 10 gms., agar 15 gms., in a litre of distilled water.

Effect of a Bacterium on the Formation of Perithecia.

When *Rosellinia* was first isolated from the air of the apple orchard, it was found to be associated with a bacterium. After the fungus has been freed from bacterium it was found that the cleaned *Rosellinia* does not produce perithecia in the standard medium although abundant perithecia formed in plain agar. Formation of perithecia in the standard medium thus seemed to be conditional to the presence of the bacterium in the culture. Experiments were made to test this point by growing *Rosellinia* and the bacterium in different degrees of proximity in the standard medium. Twelve plates of the standard medium were prepared. Four of these were inoculated with the bacterium and the *Rosellinia* mycelium placed contiguously at the centre (Series A). Four other plates were inoculated in two places each, one of the inoculum being of the fungal mycelium, the other of the bacterium placed about 4 cm. apart (Series B). The remaining four plates were inoculated at the centre with *Rosellinia* only (Series C).

The result showed that :—

1. *Rosellinia* freed from the bacterium cannot produce perithecia in the standard medium.
2. The perithecia are relatively more numerous in cultures where the bacterium and the fungus are grown together than in cultures where the growths from both are allowed to intermingle. In the latter case only a few perithecia are formed along the line of contact of the bacterium and the fungus.

The rate of advance of *Rosellinia* in Series A is relatively slower than that in either Series B or C. A brown substratal colour is formed in cultures of series A extending beyond the advancing margin of the fungus in form of a zone which attained a width of 2–2·5 cm. in cultures of 2 weeks growth. The colour is not produced in the Series C cultures. In B it is only faintly evident in that region where the fungal growth mingled with the bacterium.

As the changed acidity of the medium due to bacterial activity may be responsible for this production of perithecia the pH value of the media in which *Rosellinia* was growing was tested using B.D.H. Capillator.

One plate each from Series A and C was employed and different regions of cultures of two weeks growth were tested the results are as follows :—

1. The standard medium with pure growth of *Rosellinia* (no perithecium) .. .. pH 7·4
2. Superficial layer of the medium (5 mm. deep) containing the bacterium *Rosellinia* mycelium and perithecia .. .. .. ,, 7·7
3. A layer of the medium (5 mm. deep) below 2 .. .. ,, 8·2
4. Superficial layer of the medium from the brown zone beyond the advancing margin of the fungus (5 mm. deep) .. ,, 7·7
5. A layer of the medium (5 mm. deep) below 4 .. .. ,, 7·9

The following two points are at once evident :—

1. Relatively greater alkalinity of the lower stratum of the medium than the upper.
2. Relatively greater alkalinity of the layer of the medium producing perithecia.

As perithecia were found in that layer of the medium where alkalinity was relatively higher, it seemed not unlikely that formation of perithecia in the standard medium can be induced by altering its alkalinity but all attempts in this direction proved unsuccessful.

Effect of Certain Chemicals on the Formation of Perithecia.

Effect of Agar.—It had been observed that abundant perithecia developed when *Rosellinia* was grown in 1·5 % plain agar. Some experiments were therefore made in order to ascertain the most favourable agar concentration for production of perithecia. The following concentrations were employed :—

0·5, 1·0, 2·0, 4·0, 8·0 and 12·0 per cent.

The results are shown in Table I.

TABLE I.
Showing the Effect of Agar Concentrations on the Production of Perithecia.

Agar in gms. per cent.	Diameter of the Cultures in mm.		Perithecia	
	48 hrs.	72 hrs.	Time required for development in days	Character
0·5	18	40·0	10	A few scattered, mostly immature.
1·0	25·0	51·0	10	A large number, mature.
2·0	31·0	65·0	7	Abundant, big, mature.
4·0	33·0	72·0	6	Abundant, small, mature.
8·0	40·0	82·0	5	Abundant, very minute, mature.
12·0	40·00	80·0	5	Abundant, very minute, mature.

Table I shows that the rate of mycelial growth increases with the increase in the concentration of agar. As regards perithecia formation, at the lowest concentration employed (0·5 %) perithecia are few and most of them immature. When the concentration is increased to 1·0% a large number of perithecia are formed which are mostly mature. With the further increase of the concentration to 2·0% abundant, big, mature perithecia are obtained. In 4·0 and 8·0 % the perithecia are still more numerous but smaller in size than those found in 2% agar. At 12% the perithecia are innumerable and minute. As will be seen from the table the concentration also affects the time required for the development of perithecia. At lower concentrations (0·5 and 1·0%) longer time is required than at higher concentrations.

The effect of agar concentration must be due to the increase of the nutritive salts present in the agar as impurities. The decrease in the water-content and the relative hardness of the substratum may also be the contributory causes.

Effect of Nitrogen.—Two sources of nitrogen, asparagin and potassium nitrate, were investigated for their possible effect.

Asparagin.—Rosellinia was grown in agar medium having different concentrations of asparagin. The plates were examined periodically, but the number of perithecia formed was not counted excepting for plates having a very small number. The results obtained with cultures five weeks old are given in Table II.

TABLE II.

Showing the Effects of Asparagin on the Formation of Perithecia.

Asparagin in gms. per 100 c.c.	Number of perithecia	Nature of perithecia	Remarks
0·0	Moderate	Mature	
0·1	Abundant	,,	
0·2	,,	,,	
0·2	,,	,,	
0·5	,,	,,	
1·0	,,	,,	
2·0	Six	,,	
5·0	..	..	Medium failed to set. Very slight growth.
10·0	Eight	Mature	Medium failed to set properly. The asparagin crystallised out. Very slow growth of the fungus.

It will be seen from Table II that with the slight addition of asparagin (0·1%) there is an increase in the number of perithecia formed which continues for all concentrations upto 1·0%. Perithecia which develop in all these media are mature and produce normal ascospores. At the higher concentrations, however, the results are different. Only six perithecia appeared at 2·0% asparagin, all of them mature. At 5·0% the medium failed to set and the growth of the fungus was greatly retarded and no perithecia developed. At the still higher concentration of 10% asparagin—the highest concentration employed—the result is anomalous. The medium does not set, the fungus grows at a slower rate and a few normal perithecia are formed—the number being more than that obtained with 2% asparagin. This anomalous result is probably to be explained by the fact that due to over-saturation asparagin in this medium crystallised out.

Potassium Nitrate.—The effect of different concentrations of KNO_3 were ascertained in the usual manner. The experiment was repeated, the number of perithecia varied each time, but the trend of the results was the same. The results of one of the experiments with the concentrations employed

are given in Table III. The dimensions given are the average of 20 perithecia taken out at random.

TABLE III.

Showing the Effect of KNO_3 on the Production of Perithecia.

KNO_3 in gms. per 100 c.c.	Diameter in mm. 4 days growth	No. of perithecia	Nature of perithecia	Dimension of perithecia in μ				
				Average length	Average breadth	Average length of neck	Range of variation	
							Length	Breadth
0·00	80	800	Mature	450	290	105	350–500	240–350
0·03	78	728	,,	418	275	109	291–436	200–310
0·06	80	773	,,	418	275	90	364–473	200–328
0·1	78	440	,,	410	290	125	364–455	236–310
1·0	88	424	,,	420	280	125	346–473	218–328
1·5	90	448	,,	400	291	125	364–455	236–346
2·5	84	270	,,	455	280	180	383–510	254–346
7·5	42	..	..	..	..	..	..	..
15·0	..	..	..	..	..	..	..	..

It will be seen from Table III that the number of perithecia formed shows a gradual decrease with the increasing concentration of KNO_3. An appreciable drop in the number of perithecia occurs at a concentration of 0·1%, another drop at 2·5% KNO_3. At a still higher concentration of 7·5% while the growth rate of the fungus is halved, the formation of perithecia stops altogether. The concentration of KNO_3 seems to have little effect on the size of the perithecia formed. In all those cases where perithecia develop, they are mostly fertile, the smaller perithecia sometimes failing to produce the asci or ascospores. The perithecia become visible on the 7th day usually, but at higher concentrations these take longer to mature.

Effect of C/N Ratio.—The effect of the C/N ratio on the development of perithecia was determined by growing *Rosellinia* in all possible combinations of KNO_3 (0·00%, 0·01%, 0·03%, 0·09%, 0·27%, 0·81% and 2·45%) and glucose (0·00%, 0·018%, 0·054%, 0·16%, 0·48%, 1·46% and 4·37%). The combinations employed can be seen from Table IV.

The plates were examined in great detail and the rate of advance of the fungus, the formation of perithecia, their number, dimensions, the colour of the substratum and all such points were carefully noted.

The number of perithecia formed at different concentrations and the average dimensions for twenty perithecia taken at random are shown in Table IV. The italicised figures indicate the perithecia number.

TABLE IV.

Showing the Relative Number of Perithecia formed in Different Combinations of KNO_3 and Glucose and their Average Dimenisons in μ.

KNO_3 in gms. per 100 c.c.	Glucose in gms. per 100 c.c.						
	0·00 *a*	0·018 *b*	0·054 *c*	0·162 *d*	0·486 *e*	1·458 *f*	4·374 *g*
0·00 A	521×270 *1376*	482×270 *1775*	412×238 *1938*	360×248	..	..	..
0·01 B	550×291 *1220*	458×286 *1880*	571×280 *2080*	331×210	..	..	..
0·03 C	388×257 *1160*	433×211 *1580*	455×265 *2300*	198×172 Innumerable minute	..	..	..
0·09 D	393×258 *980*	448×265 *1610*	484×261 *1980*	222×180 Innumerable minute	..	..	..
0·27 E	44×273 *1060*	455×263* *1880*	495×28 *1584*	192×168 Innumerable minute	..	..	..
0·82 F	466×280 *656*	467×270* *1808*	491×261* *1550*	157×140* Innumerable minute*	..	..	..
2·45 G	535×313 *542*	491×273* *1220*	561×241* *1558*	150×109* Innumerable minute	..	..	..
7·35 H	..	..	..	..	..	..	..

* Indicate perithecia without asci.

It will be seen from Table IV that C/N ratio has practically no effect on the production of perithecia. The number of perithicia formed shows a slight increase with the increase in glucose concentration. The greatest increase is, however, obtained in media combining 0·162% glucose content with relatively high KNO_3 content (0·03%–7·35%) where innumerable minute perithicia develop. It is thus apparent that the effect is not so much due to the C/N ratio as to the combined effect of the high concentrations of the two chemicals.

At a concentration of 7·5% KNO_3 no perithecia develop irrespective of the glucose content and that glucose inhibits the perithecia production at a very moderate concentration of 0·486% irrespective of the concentrations of KNO_3. It should be noted in this connection that in all those combinations where perithecia are not produced, the fungus grows quite actively. In fact, there is hardly any difference in the growth rate of the fungus at any combination of glucose and KNO_3 employed.

As regards the nature of perithecia produced C/N ratio has hardly any effect. Normal and large perithecia were produced in all the following media : Aa, Ba, Ca, Da, Ea, Fa and Ga ; Ab, Bb, Cb and Db ; Ac, Bc, Cc, Dc and Ec ; Ad, Bd, Cd, Dd and Ed. In all other combinations Eb, Fb, Gb ; Fc, Gd the perithecia proved to be mostly immature or half mature. A scrutiny of these results shows that in the absence of glucose the increase in KNO_3 content does not have any effect on the maturity of the perithecia, that is, asci and ascospores found in the perithecia are the same as in normal agar culture. The immaturity and the semi-maturity of the perithecia are seen in media with high content of KNO_3 (0·27%, 0·82% and 2·45%) to which glucose (0·018%, 0·054% and 0·162%) is added. At 0·162% of glucose, in the absence of KNO_3 or when KNO_3 is added in the proportion of 0·01%, the perithecia produced are normal. When KNO_3 concentration is increased (0·03%, 0·09% and 0·27%), the perithecia produced are distinctly smaller and the number is correspondingly large and almost all of these are mature. With still higher concentration (0·82% and 2·45%) innumerable small immature perithecia without asci and ascospores are formed.

Rosellinia does not produce any colour in ordinary culture medium. While working with the C/N ratio series, it was observed that in all the media containing 0·486, 1·458 and 4·374 per cent. of glucose in combination with various concentrations of KNO_3 showed brown and yellow colour in the substratum, the colour being more intense in the marginal regions of the cultures.

Effect of Acidity and Alkalinity.—The effect of the acidity and alkalinity of the medium on the production of perithecia was found out by altering the acid and alkali content of agar by the addition of malic acid and ammonium carbonate respectively.

Acid Series.—*Rosellinia* was grown in agar with different concentrations of malic acid, and the plates were examined for perithecia periodically. Wherever perithecia developed the first visible sign appeared usually after six days growth. Most of the perithecia were superficial, a few being completely immersed in the medium. Cultures of 44 days growth were used for final counting. The various concentrations employed and the result obtained are shown in Table V along with the diameter of the cultures of

three days growth. The number of perithecia is given in round figure. The pH was taken by the B.D.H. capillator method.

TABLE V.

Showing the Effect of Acid on the Production of Perithecia.

Acid Conc. in gms. c.c.	Initial pH of the medium	Diameter of cultures in mm. (3 days growth)	Number of perithecia in cultures of 44 days growth
0·002	6·1	56	540
0·004	5·9	58	560
0·008	5·3	58	500
0·016	5·0	50	640
0·032	4·7	26	850
0·064	4·1	24	600
0·128	3·9	4	300
0·256	3·1	..	..

The acidity of the medium has very little effect on the number of perithecia formed by the fungus. Until a very high dose of malic acid is administered the perithecia are quite abundant.

The type of perithecia formed, however, showed a good deal of difference. In general, the perithecia are mature but at high concentrations of acid these tend to become very small, infertile, and immersed.

A comparison of growth rate of the fungus at different concentrations shows that up to the concentration of 0·016% (pH 5·0) the effect of acid on the rate of the growth of *Rosellinia* is very little. A distinct retardation is, however, seen at 0·032% (pH 4·7) and 0·064% (pH 4·1). At a still higher concentration of 0·128% (pH 3·9) the growth is extremely feeble and reaches only 4 mm. on the third day as opposed to the 24 mm. at 0·064%. No growth was observed at 0·256% concentration (pH 3·1).

Alkalinity.—Rosellinia was grown in different concentrations of ammonium carbonate and the effect of the concentration was found out by counting the number of perithecia in cultures of 44 days growth in the same way as in the acid series. The results of the count which is average for two plates are given in Table VI, along with the diameter of the fungus growth. The pH value of the alkaline series is not given since at higher concentrations of

alkali the media developed a colour which interfered with the finding of pH by colorimetric method.

TABLE VI.

Showing the Effect of Alkali on the Production of Perithecia.

Ammon. carb. in gms. p.c.	Diameter of colony in mm. (3 days growth)	Number of perithecia in cultures of 44 days growth
0·0	56	800
0·0016	52	780
0·0035	56	640
0·007	54	960
0·015	56	720
0·03	52	520
0·06	56	360
0·12	56	400
0·25	54	240
0·5	44	400
1·0	16	480
2·0	..	..

The result indicated that in slightly alkaline medium the perithecial development is favourable, but at higher concentrations the number falls off. The size of the perithecia tend to become smaller as the concentration increases and many of them appear infertile and immature.

It is realised that both in acid and alkali series the number of perithecia is bound to vary from plate to plate and with each experiment. Nevertheless the results probably correctly indicate the relative abundance of perithecia at different concentrations of acid and alkali.

Regional Distribution of Perithecia in Culture.

In the course of the experiments described in the foregoing pages, it was observed that in cultures where perithecia were produced the fertile and infertile regions varied both in extent and in their relative positions, with the type of the medium employed.

In plain agar medium (1·5%) the perithecia were invariably found to grow at the central region of the culture while the peripheral region remained completely infertile. Similar was the case when the concentrations employed were 0·5% and 1·0% agar. But as the concentration increased from 1·5% to 12·0%, the fertile zone gradually receded towards the periphery leaving an infertile region at the centre. A closer inspection showed the presence of a very narrow infertile zone at the periphery as well.

Addition of glucose to the plain agar medium brought about the same result. At 0·018% glucose a distinct infertile region appeared in the centre which increased in size as more and more glucose was added (0·054, 0·162); the fertile region becoming correspondingly narrow. Almost similar results were obtained with the lower concentrations of asparagin (0·1% — 1·0%). At higher concentrations (excepting at 5·0% where no perithecia appeared) only a very few perithecia developed and all those were restricted at the central region of the culture.

In the case of the potassium phosphate (K_3PO_4) series which has been dealt with in an earlier paper (Das Gupta, 1937), the potassium nitrate series, the acid series and the alkali series, the results were different. It was found that these did not have any appreciable effect on the regional distribution of perithecia. In the case of K_3PO_4, for example, the perithecia developed mostly in the central region at the lowest concentration employed (0·10%), only a few being found at the peripheral region. At higher concentrations a much larger number of perithecia was found at the peripheral region and a comparatively few at the centre. Only at the concentration of 0·3% of K_3PO_4 did the central region prove completely infertile. Neither the addition of acid had any appreciable effect on the distribution of perithecia, that is to say, the perithecia remained restricted to the centre as in plain agar medium. With the addition of alkali to the agar medium two fertile regions appeared in the culture one central, the other peripheral, separated by a narrow, irregular, infertile zone.

Some experiments were made to ascertain the behaviour of the fungus when larger and smaller area are given for growth. Petri-dishes of three sizes were employed, namely, 15 cm., 10 cm. (normal) and 7 cm. diameter, and media used were those in which infertile zone was known to appear. It was found that in larger dishes correspondingly larger infertile central zone appeared indicating that the regional distribution of perithecia is probably related to the accumulation of staling products.

Discussion.

The results obtained from this investigation supplement those already published in a previous paper (Das Gupta, 1937). It has been definitely shown

that in the standard synthetic medium the *Rosellinia* sp. employed for investigation cannot produce perithecia unless associated with a species of bacterium. The perithecia are most abundant when the fungus and the bacterium are grown together but when the two growing side by side come in contact with each other only a few perithecia are irregularly formed at the line of junction. This fact of the stimulating effect of bacteria on the production of fruit-bodies is well known and has been noted by many authors. Attempts to ascertain the cause of the stimulating effect, however, proved unsuccessful. It is shown that the contaminated mycelium forming the perithecia give higher alkaline reaction than uncontaminated mycelium not producing perithecia. That alkalinity is not the factor controlling the perithecia formation has been shown experimentally by growing the uncontaminated fungus in alkaline condition. The controlling factor is probably a nutritional one.

The increase in the number of perithecia with the increase in agar concentration might be due to the relative increase of nutritive salts present in agar. The decrease in the size of the perithecia seems, on the other hand, to be due to the reduced water content and the firmness of the substratum.

Nitrogen content of the medium does not play a prominent part in the production of perithecia. Both asparagin and potassium nitrate as sources of nitrogen behave similarly in this respect. The perithecia number decreases as the concentration is increased except at a low concentration of 1% asparagin where a slight increase in the perithecia number is observed. This is in spite of the fact that the vegetative growth of the fungus as measured by its rate of advance remains practically the same in all concentrations except in very high ones.

The results obtained with acid and alkali series are very similar except that in both the cases perithecia are produced even at those concentrations where mycelial growths are greatly reduced. Here too, as in others at high concentrations, the perithecia tend to become small and infertile and in acid series particularly to grow immersed in the medium.

When carbon nitrogen ratio is altered the effect on the perithecia development does not seem to be very great. Whatever effects are observable they are not so much due to the C/N ratio, as to the the combined effect of the high concentrations of the two chemicals. An appropriate example is the perithecia formed at 0·162% glucose in combination with 0·03, 0·09, 0·27, 0·82 and 2·45% KNO_3. In the first three combinations the perithecia formed are minute and innumerable but nevertheless mature. In fact, it is a reduced form of normal perithecia where the fertility of the fruit-bodies, that is the capacity of producing asci and ascospores, has not been affected. But

in the last two combinations (0·162% glucose with 0·82 and 2·45% KNO_3) the reduction proceeds still further and the perithecia produced are both small and infertile.

The infertile and semi-infertile condition of the perithecia are also found in media having similar concentrations of KNO_3 (0·82% and 2·45%) but less of glucose (0·018% and 0·054%). The size of the perithecia, however, is in these cases comparatively bigger. It should be further noted that in the complete absence of glucose, KNO_3 does not affect the production of asci and ascospores. Glucose therefore seems to exert a deleterious effect not only on the production of perithecia (Das Gupta, 1937) but also on the fertility of those which are produced when combined with certain concentrations of KNO_3. The immature and infertile condition of the fruit-bodies have been correlated to the increase in the glucose content together with the high KNO_3 content in the medium. It is to be noted, however, that both in the acid and in the alkali series at high concentrations employed the perithecia appear as small infertile bodies usually immersed in the medium ; but even in these small perithecia the asci and ascospores do not show any deviation from the normal one, excepting that they take longer to mature. Similarly in high agar concentrations, however small the perthecia, they are usually mature.

A consideration of facts regarding the regional distribution of perithecia suggests that the phenomenon is in some way connected with the altered condition of the media due to the accumulation of staling products in the advancing region of culture. Further work will be required before it is possible to arrive at any definite conclusion.

Summary.

The present paper deals mainly with the effect of various chemicals (asparagin, KNO_3, acid, alkali and C/N ratio) on the production of perithecia in a species of *Rosellinia* and supplements the results given in a previous paper (Das Gupta, 1937). The stimulating effect of a bacterium on the formation of perithecia is briefly dealt with.

The following are the main points :—

The *number of perithicia* formed in a medium decreases with the increase in the concentration of asparagin, potassium nitrate, acid and alkali. In simple agar medium the higher agar concentration the greater the number of perithecia formed. Innumerable perithecia appear in media combining relatively high content of potassium nitrate with moderate amount of glucose.

The *size of the perithecia* is only slightly reduced in media combining relatively high concentration of asparagin and potassium nitrate with low

concentrations of glucose. The size is greatly reduced in the media where KNO_3 content and glucose content are both relatively high.

Addition of glucose in a medium having relatively high KNO_3 content has a *deleterious effect on the production of asci and ascospores.*

Development of perithecia is inhibited much before the vegetative growth of the fungus is retarted due to high concentrations of chemicals except in the cases of the acid and alkali series where the perithecia develop as long as vegetative growth is not totally checked.

Regional distribution of perithecia in different modified media is briefly dealt with.

LITERATURE CITED.

Das Gupta, S. N., "On the culture behaviour of a species of *Rosellinia*—I. Inhibitory effect of certain chemicals on the production of perithecia," *Jour. Ind. Bot. Soc.*, 1937, 16.

A MICROSCOPICAL STUDY OF THE DEVELOPMENT OF *TRICHOGRAMMA MINUTUM* RILEY (THE EGG-PARASITE OF THE SUGARCANE BORERS IN MYSORE) AND ITS PARASITISATION OF THE EGGS OF *CORCYRA-CEPHALONICA* STAINT (THE FLOUR-MOTH EMPLOYED IN THE MASS PRODUCTION OF *TRICHOGRAMMA*.

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Trichogramma minitum, Riley, the tiny Hymenopterous egg-parasite has attracted considerable attention by virtue of its being a highly useful and easily-handled agent in the biological control of the stem-borers of sugarcane in most countries where the crop is grown.

Subramanyam has described in detail the manner in which the parasite is produced on a large scale in Mysore, in the laboratory.[4]

Material and Methods.—The material for the microscopical studies of the parasitisation was prepared as follows :—

Empty and oversized parasite cards were first of all, ruled up into squares varying in number between 50 and 100 and in each of the squares not less than 100 host eggs (of *Corcyra cephalonica*—the flour moth) were pasted to form a single and even layer ; several sets of eggs on separate cards were thus pasted ; each card was, later,—introduced into suitable glass tubes containing freshly-emerged *Trichogramma* parasites, their number varying from two to five thousand. The tubes were placed in the dark for one to two hours ; the cards were then taken out of the tubes and deposited in other separate, dry tubes, having a piece of wet cotton sticking inside through the centre of the cork.

The first square with its egg cluster on the cards was cut out, an hour afterwards and the parasitised host-eggs were fixed in Carnoy and Le Brun's fluid, for about thirty minutes. The other egg clusters were also cut out subsequently at certain regular intervals and fixed similarly. Later, the eggs were imbedded in collodion and paraffin and 6 μ thick sections were taken and stained in Heidenhain's iron hæmatoxylin and counter-stained in eosin. A series of different developmental stages of the parasite within the host-egg was thus obtained and studied.

Some stages in the embryonic development of the parasite illustrated in this paper are (1) Early clevage (Plate III–A), (2) Blastoderm (Plate III–B), (3) Nearly total clevage, characteristic of Hymenopterous endoparasitic development (Plate III–C), (4) Invagination and formation of primary layers (Plate III–D.), (5) Differentiation of stomodeum, midgut, and proctodeum, denoting the rudiments of the digestive tract (Plate IV–A), (6) Embryo and its segmentation (Plate IV–C), (7) Larval (Plate I–D), (8) Pupal (Plate II–A–B), and (9) Imaginal stages, (Plates II–C, D ; V–A, B).

Factors about the Life-history, Host Preference and Behaviour of the Parasite and Their Importance.—The female is found to limit its preference in oviposition, generally, to three-days old host-eggs. A number of separate parasite cards with equal number of host-eggs, of different ages namely, 24, 48, 72 and 96 hours were prepared and introduced into tubes containing equal numbers of freshly-emerged parasites ; about 96 hours later, the cards, showing varying numbers of host-eggs turned black[4] were removed from the tubes and counts of blackened eggs in all the tubes taken. The average percentages of parasitisation as judged by the number of blackened eggs, for six sets of trials, were found to be 90, 87, 82 and 29. Host-eggs older than 72 hours, thus appear to be unsuitable for oviposition by the female.

Whether the female chooses only fresh host-eggs untouched by other female individuals, for oviposition or oviposits also in those that have already been used, has not been quite clear ; nevertheless, many females have often been noted to thrust their ovipositors in eggs already attacked by other individuals ; while some were observed to withdraw the ovipositor soon after its insertion, others let it continue in the host-eggs for a full minute or more, apparently engaged in the act of depositing one or more eggs ; in the latter case, it is probably to be understood, that, provided, there was room enough inside the host, the female laid an egg or more of hers, also, there. It has been found to be very difficult to make out exactly how the female reacts under the circumstances and whether—superparasitism occurs or not. Salt[3] however, has stated with reference to the behaviour of *T. evanescens*, Westw, ovipositing in the eggs of *Sitotroga cerealella*. Ol. that the descriminative ability, *i.e.*, distinguishing healthy from parasitised hosts, of the parasite is perfect. But in cases where only a few host-eggs are available, or where too many parasites are confined together, superparasitism occurs.

The maximum number of parasite eggs laid in a single host-egg has been found to be 9 (Plate I–A) ; whether all the nine were laid by one individual or whether they were from more than one, is not possible to say. The greater majority of host-eggs cut up have shown only 1–2 parasite eggs in

them. The number largely depends upon the density of the parasite population in the parasitising tube and the number of host-eggs provided on the parasite cards. Host-eggs exposed to just the minimum number of parasites required for a fairly successful parasitisation, which can approximately be estimated at 70 per cent. when sectioned, have generally shown a single parasite egg, only a few showing two eggs and rarely more than two. On the other hand, where the parasite density is disproportionately large for the number of host-eggs on the card, the latter always show two or more parasite eggs within them. But the greater parasite density does not, by any means, produce a greater output of parasites ; the output is more or less the same, as where the parasite density is just the minimum required, all other conditions remaining the same. It is clear from this, that when more than one parasite egg is laid inside a single host, or in other words, when superparasitism occurs, generally only one and sometimes two adult individuals emerge out ; where two individuals develop, they are mostly found to be sub-normal in size (Plate I–B) The other parasite eggs are seen to gradually dwindle and disintegrate. This is fully borne out by the study of the sections taken of differently treated host-eggs. More than one factor, such as crowding in and starvation, may account for the dwindling away of all but the most favoured and vigorous (Plate I–C).

These observations with reference to *T. minutum*, made by the writer, largely confirm, several of the conclusions arrived at by Salt, in his work on the oviposition behaviour of *T. evanescens*, Westw.

These factors about the development of *T. minutum* inside the host, have a definite bearing on its mass production. They show clearly that it should be wasteful to have the density of the parasite population in the parasitising tubes anything more than the minimum required for obtaining the maximum output of adult individuals. There is a definite possibility of reducing appreciably, the number of parasites now generally supplied to a certain known number of host-eggs on the parasite cards, without, at the same time, diminishing the percentage of successful parasitisation or in other words the final output of adult parasites. Experiments in this direction have been started and are expected to lead to a greater economy in the use of the parasite in mass production.

The parasitised host-egg usually turns dark about the fourth day after exposure to the parasite ; microtome sections of such an egg reveal that the developing parasite inside is reaching the stage of the larva (grub) and its body integument is getting pigmented (Plate I–D). The pigment shows up through the chorion of the host-egg and becomes deeper and deeper as development proceeds further. This pigmentation of the developing parasite

at a particular stage, is a very useful guide in determining the extent of successful parasitisation in mass production work, without having to wait for the actual emergence of the fully-formed adults, which comes off only four to six days later.

The larva is transformed into a pupa about six days after development starts (Plate II–A, B) and the imaginal stage is reached on about the eigth day (Plate II–C) and the adult is found ready to emerge on the ninth day (Plate II–D). During the period when these studies were made, *i.e.*, November 1936-February 1937, the period from time of parasitisation to emergence of adult, has been found, not only through examination of serial sections but also from direct observation of control sets of parasite cards, to range from 9 to 11 days which confirm the results obtained by Subramanyam.

The development of the host appears to be arrested by the rapidly growing parasite body inside it, almost as soon as the clevage nuclei of the parasite egg begin to form.

Acknowledgements.

I have to thank Mr. T. V. Subramanyam, Entomologist, for his encouragement ; my thanks are also due to Mr. S. V. Venkatarayan, Senior Assistant Mycologist, and Mr. H.A. Abdur Rubb, Junior Assistant Entomologist, for their kind help in photomicrography.

REFERENCES.

1. Korschelt and Heider .. *Text-book of the Embryology of Invertebrates.*
2. Peterson, A. .. .. "A Biological study of *Trichogramma minutum*, Riley, as an egg-parasite of the Oriental Fruit moth." *Technical Bulletin, U.S.D.A.*, November 1930, No. 215.
3. Salt, G. .. .. .. "Experimental Studies in Insect Parasitism." (iv) The effect of super-parasitism on populations of *Trichogramma evanescens*," *J. Exp. Biol.*, July 1936, **13**, 3; *Rev. Appl. Ent.*, January 1937, **25**, Ser. A.
4. Subramanyam, T. V. .. "Preliminary experiments on the mass production of *Trichogramma* parasites for control against sugarcane borer in Mysore," *Ind. Jour. Agric. Sci.*, Feb. 1937, **7**, Part I.

EXPLANATION OF PLATES.

PLATE I. A.—Nine parasite eggs in a single host-egg. × 125.
B.—Two larvæ forming in a single host egg. × 125.
C.—One parasite egg, out of the four, laid in one host-egg, developing normally and the other three disintegrating. × 250.
D.—Larva (grub). × 500.

PLATE II. A.—Pupa with rudiments of wings, etc.

(*a*) Head.
(*b*) Eye.
(*c*) Wings.
} × 125.

B.—Longitudinal section of pupa. × 250.

C.—Longitudinal section of post-pupal and early-imaginal stage. × 350.

D.—Nearly fully-formed adult as seen through the embryonal covering. × 250.

PLATE III. A.—Parasite egg, nearly 1 hour old; the initial clevage cells are forming and migrating to the periphery. × 500.

B.—Parasite egg, nearly 3 hours old. × 250.

C.—Two parasite eggs (one longitudinally and the other transversely cut) showing nearly total clevage. × 500.

D.—Three parasite eggs, showing the stage of the formation of layers.

(*a*) Ectoderm.
(*b*) Mesoderm.
(*c*) Amnion.
} × 500

PLATE IV. A.—Longitudinal section of parasite egg showing the rudiments of the digestive tract.

(*a*) Stomodeum.
(*b*) Midgut.
(*c*) Proctodeum.
} × 500.

B —Same as in A showing in addition the development of the epithelial layer of the midgut.

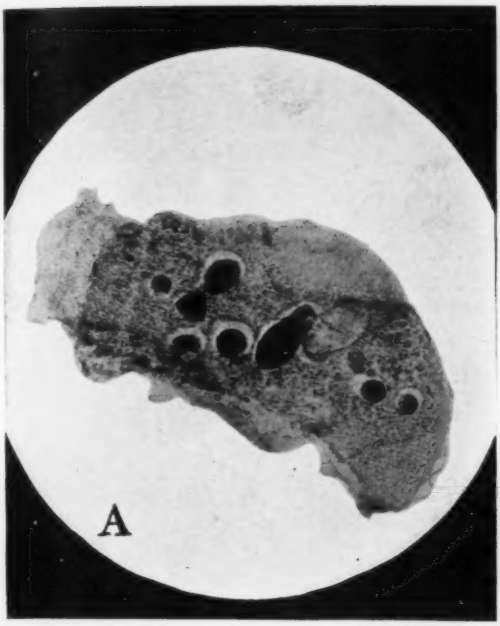
(*a*) Epithelial layer. × 500.

C.—Early segmentation of the embryo. × 500.

D.—A later stage of the embryo. × 250.

PLATE V. A.—Adult parasite, Female. × 125.

B.—Adult parasite, Male. × 250.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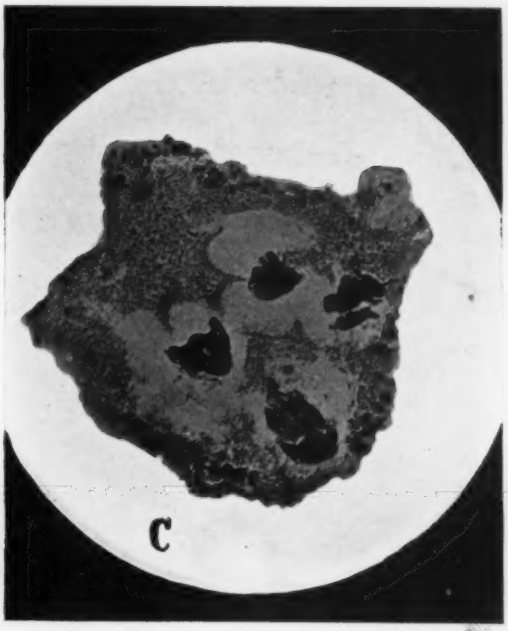
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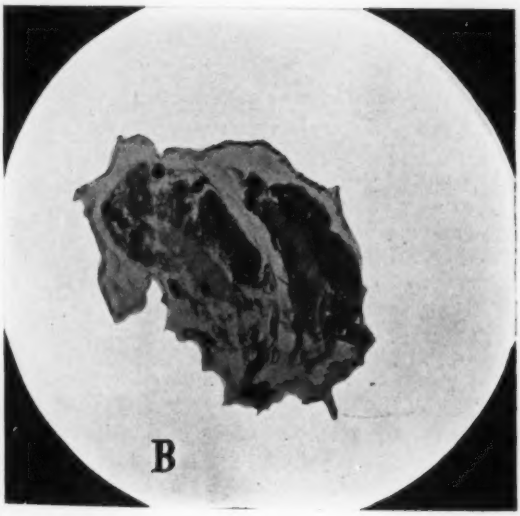
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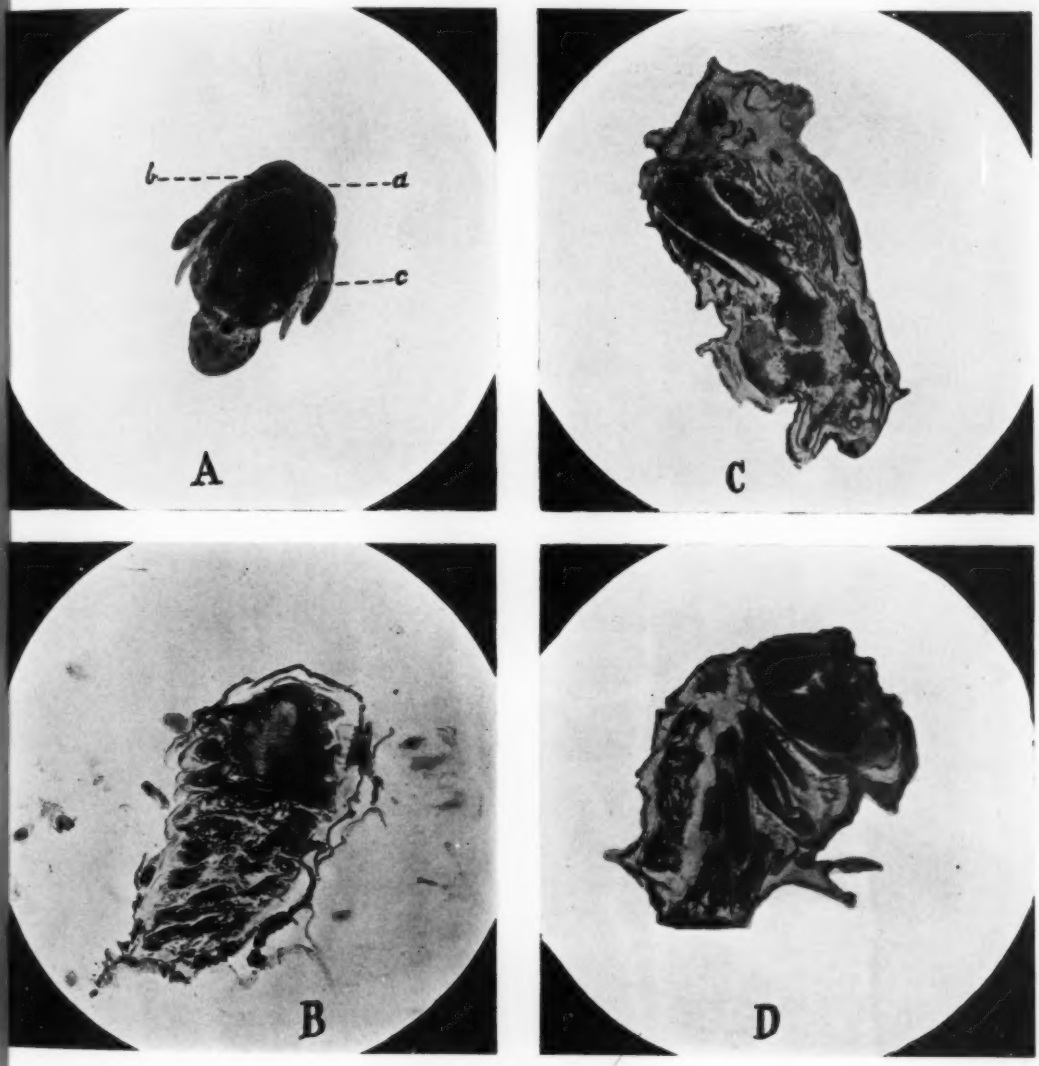
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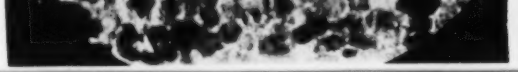

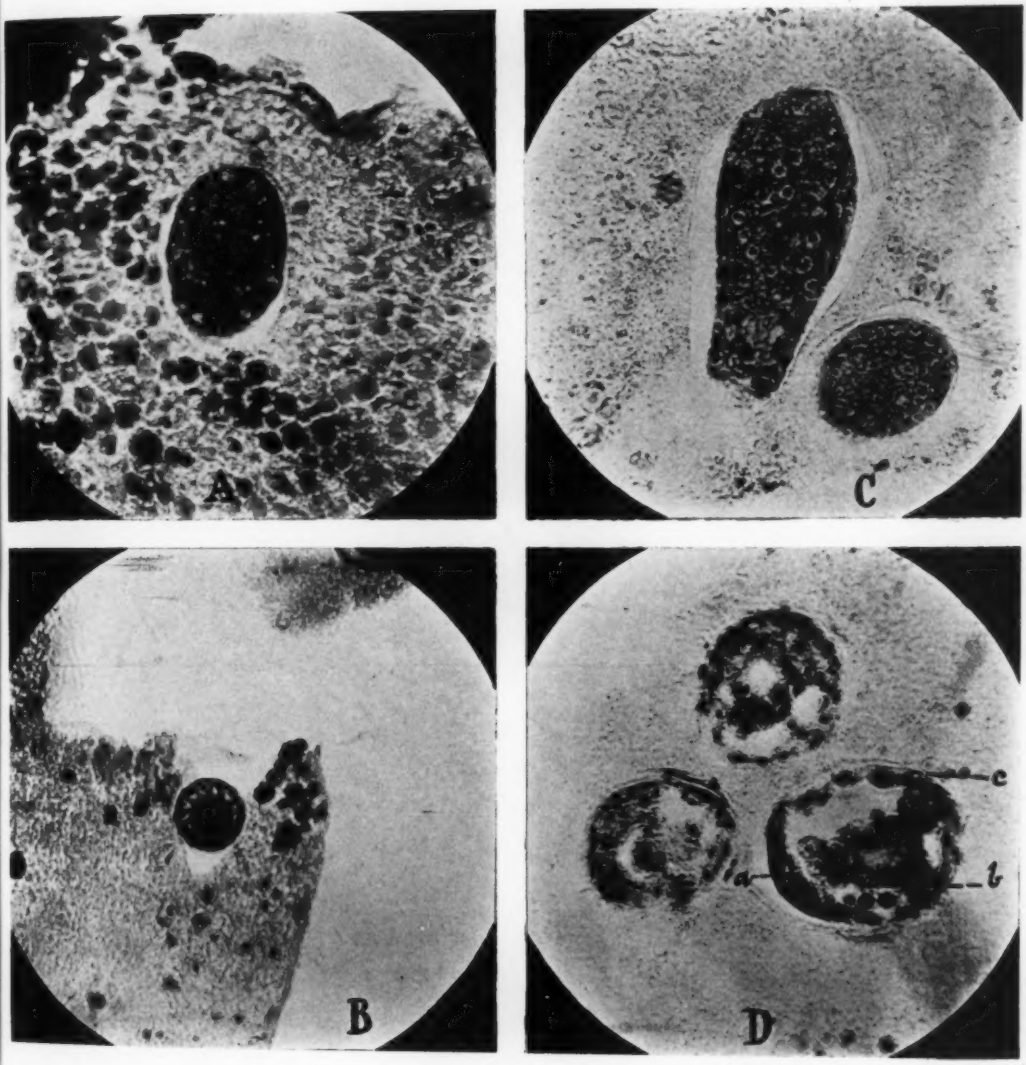
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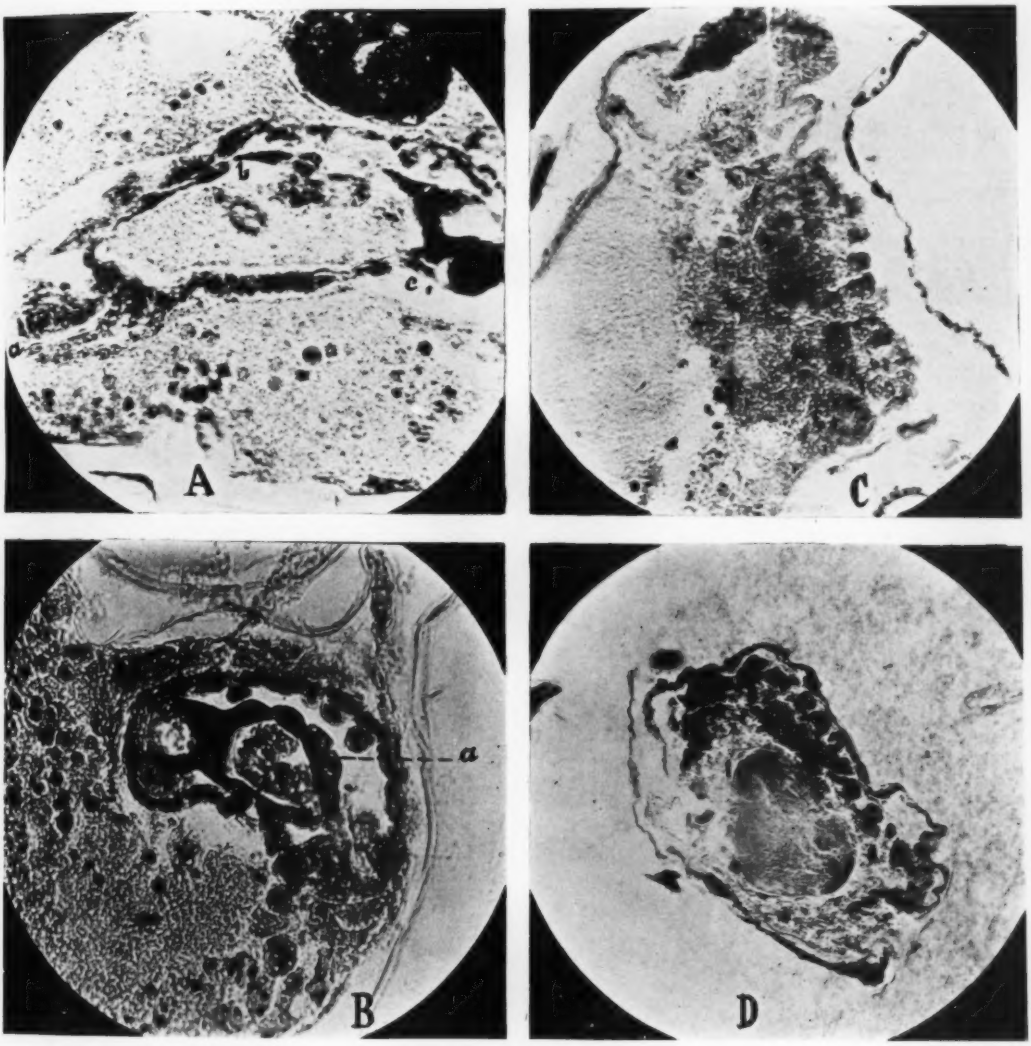
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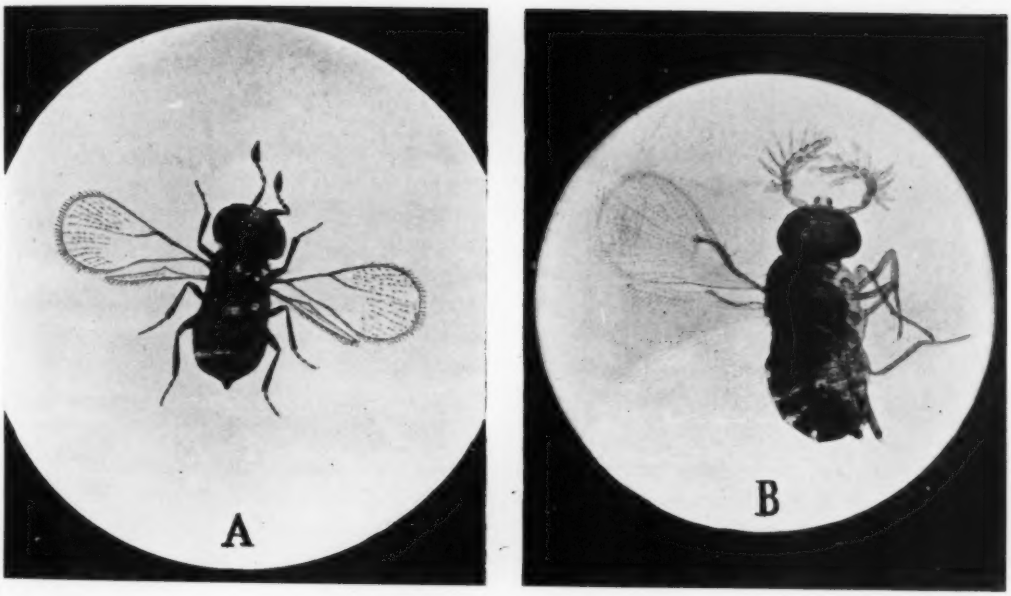
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ON A NEW SPECIES OF ACANTHOCEPHALA, *ACANTHOSENTIS HOLOSPINUS* SP. NOV. FROM THE FISH *BARBUS STIGMA* (CUV. AND VAL.).

By P. Sen, M.Sc. (Cal.), Ph.D. (Lond.), D.I.C.
(*From the Bengal Public Health Department, Calcutta.*)

Received November 24, 1937.
(Communicated by Prof. C. R. Narayan Rao, M.A.)

While analysing the intestinal contents of the fish *Barbus stigma* (Cyprinidæ) in connection with my work on the food factors of the so-called larvicidal fishes of Bengal (Sen, 1937) I came across with a worm, which on examination proved to be a new species of Acanthocephala. Afterwards more specimens of this parasitic worm were obtained by careful searches of the fish guts. Altogether about 20 specimens were collected. All the specimens were flattened between two slides and preserved in 70 per cent. alcohol. A few were stained in Delafield's Hæmatoxylin. The morphology and anatomy of the parasites could be studied clearly even in alcohol-glycerine preparations when the specimens became very transparent.

The colour of the worm is whitish or creamy. Sexual dimorphism is well exhibited, there being a distinct differentiation in the measurement of the male and female specimens.

The females vary from 1·6 mm. to 9·4 mm. in length and 0·2 mm. to 0·7 mm. in breadth, and the males 0·9 mm. to 2·4 mm. in length and 0·2 mm. to 0·4 mm. in breadth. The measurement depends to a great extent on the state in which the specimens were killed whether in a contracted or extended condition.

The body has the broadest part somewhere towards the middle but in contracted specimens the anterior portion becomes the broadest and the body tapers somewhat towards the posterior extremity which is bluntly rounded (Fig. 1). The body is beset with spines of about 38 rows extending along the whole length of the body. The count near the middle of the body was about 34 in each row. These rows or circlets of spines are crowded anteriorly but in the posterior four-fifths of the body they are widely separated. In the anterior extremity there is a short cylindrical proboscis armed with three rows of

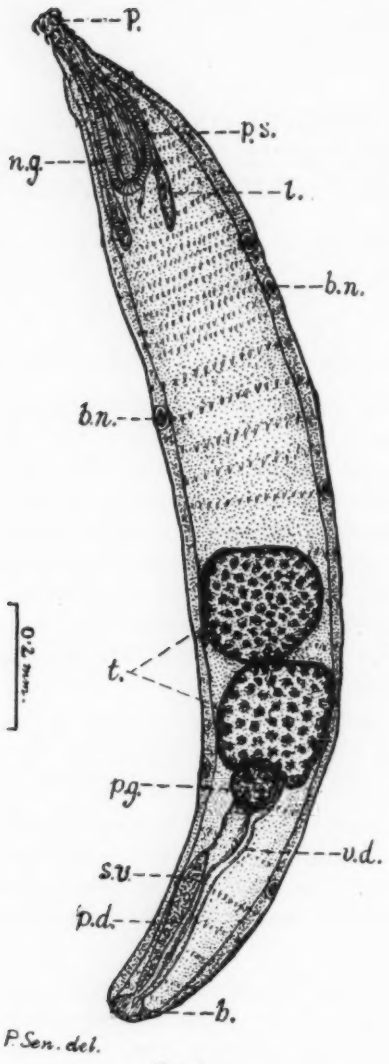

Fig. 1.

six single-rooted hooks in each (Fig. 2 A). The hooks of the anterior row on the proboscis are much stronger and larger in size, while those of the basal row are the smallest, the hooks being elegantly curved. The proboscis measures about 0·1 mm. in length and 0·05 mm. in breadth in a specimen of average size.

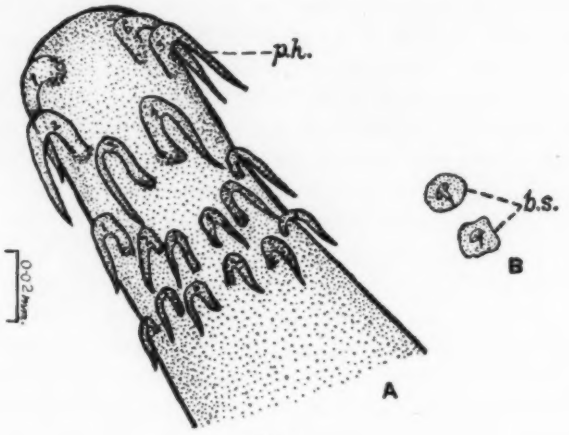

FIG. 2.

The receptacle of proboscis or the proboscis sheath is sacular with the base widened and the anterior end constricted. The sheath has a single-layered muscular wall and is provided with strong muscle bands which act as retractor and protractor muscles. The proboscis sheath of an average sized specimen measures about 0·3 mm. in length and 0·08 mm. in breadth.

The central nervous system formed by a single nerve ganglion is quite prominent and situated within the muscular layer of the proboscis sac near the posterior end.

The muscular lemnisci are two in number and very slender. These extend to a short distance beyond the proboscis sheath being longer than the latter.

The body wall is composed of an outer cuticular layer and an inner epidermal layer in which are scattered here and there a few more or less rounded or oval nuclei. There are about four body nuclei on the dorsal surface and one or two on the ventral surface of the body. Lacunar system is well developed, the canals and canaliculi being seen all over the body wall. The longitudinal and transverse muscles are well discernible in a glycerine preparation.

The male genitalia lying in the posterior half of the body consist of a pair of ovoid testes, one below the other and touching each other, two vasa efferentia, a vas deferns, an enlarged seminal vesicle, a compact prostatic gland or mass, a prostatic duct, a penis and a funnel-shaped bursa.

The two ovoid testes are almost equal in size, and from each a narrow duct, the vasa efferentia arises which unite at the region of the prostatic

gland to form the vas deferens. The vas deferens has the appearance of a great bulging which, after running a short almost straight course, narrows and ultimately terminates into the penis. The prostatic gland is more or less rounded and lies immediately behind the testes and possesses 4 to 6 large nuclei. This gland is followed by the prostatic reservoir overlying the widened seminal vesicle. A stout duct the prostatic duct arises from the prostatic reservoir and is continued posteriorly touching the vas deferens; this duct ultimately terminates into the narrow penis.

The female genitalia lying in the posterior fifth of the body consist of the ovary, the uterine bell, the guard cells, the uterus, the vagina and the vulva (Fig. 3). In mature worms the rounded egg-balls or ova owing to the bursting of the ovary are scattered all over the body-cavity beginning from the region just behind the proboscis to the posterior extremity of the body. The uterine bell is a thin funnel-shaped structure for the passage of the mature ova.

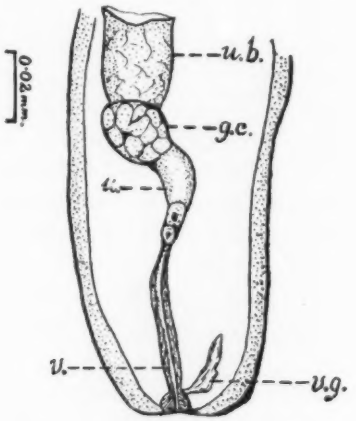

Fig. 3.

This structure is followed by the guard cells which lead into a longish uterus. The uterus is fairly wide at its commencement and thin-walled, but it narrows towards its base. In the uterine wall there are a pair of large cells, which probably have a secretory function almost blocking the passage leading from the uterus to the narrow vagina. There is also a pair of glands opening into the vagina at its posterior end near the opening of the vulva. The external pore of the vulva is situated terminally.

Several pairs of copulating forms were obtained. The vaginal end of the female (Fig. 4) appeared to be inserted into the bursa of the male which did not show any evidence of eversion as in *Centrorhynchus maryasis* Datta

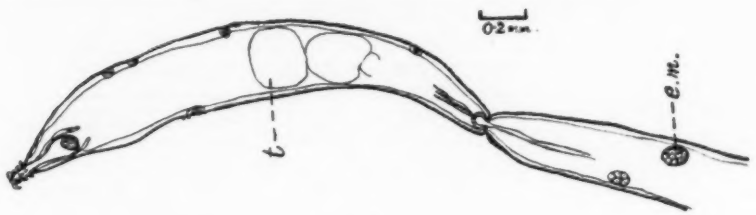

FIG. 4.

(1933). The embryos are elliptical, each being 0·1 mm. long, and they are nearly three times as long as broad.

The present species has been grouped under the genus *Acanthosentis* of Varma and Datta (1929) owing to its possessing the following characters : (1) Cylindrical proboscis with three rows of strong hooks, six in a row, (2) Absence of any distinct neck, (3) Proboscis sheath single-layered, (4) Central nervous system near the base of the proboscis sheath, (5) Rose-thorn like spines in the body (Fig. 2 B), (6) Presence of two ovoid testes and a compact prostatic gland in males, and the uterine bell in females followed by uterine ducts.

But the present worm differs from the only other described species *Acanthosentis antispinus*, the genotype of Varma and Datta (1929) in size, the newly described species being much larger in both sexes than the genotype, in possessing spines all over the body, in having much smaller and slender lemnisci, in the number of body nuclei, and in having about 4 to 6 nuclei in the prostatic gland.

Diagnosis.—The diagnostic features of the species *Acanthosentis holospinus* sp. nov. are the presence of a cylindrical proboscis with three rows of proboscis hooks having six in a row, proboscis sheath single-layered having a prominent nerve ganglion inside the sheath at its base, the lemnisci narrow and slightly longer than the proboscis sheath, the body spines rose-thorn like about 38 rows of which encirle the body extending upto the terminal end of the worm. There are four dorsal and two ventral body nuclei which may be oval or imperfectly rounded.

Host.—*Barbus stigma* (Cuv. and Val.).

Location.—Intestine.

Locality.—Salt lakes near Calcutta.

Type specimens are deposited in the collection of the Zoological Survey of India, Indian Museum, Calcutta.

In conclusion, my thanks are due to Mr. M. N. Datta, M.SC., of the Zoological Survey of India, for his readiness to discuss matters with me.

REFERENCES.

Baylis, H. A. .. .. "On some Parasitic worms from Java, with remarks on Acanthocephala genus Pallisentis," *Ann. Mag. Nat. Hist.*, 1933, **12** (10), 443–49.

Bhalerao, G. D. .. .. "On a new species of Acanthocephala from *Ophiocephalus striatus*," *ibid.*, 1931, **7**, (10), 569–73.

Datta, M. N. .. .. "Acanthocephala from Northern India. II—A New Species of *Centrorhynchus* (*C. maryasis* sp. nov.) from a Himalayan bird, *Urocissa malanocephala occipitalis* (Blight)," *Rec. Ind. Mus.*, 1933, **35**, 325–30.

Idem .. .. .. "Scientific results of the Yale North India Expedition. Biological Report No. 20. Helminth parasites of Fishes from North India, with special reference to Acanthocephalans," *ibid.*, 1936, **38**, 211–29.

Datta, M. N., & Poddar, T. N. "Acanthocephalan parasites of certain fishes from Calcutta," *ibid.*, 1935, **37**, 231–36.

Meyer, A. .. .. .. "Acanthocephala," Bronn's *Tier-Reichs*, 1933, **4**, Abt. 2, Buch. 2.

Sen, P. .. .. .. "On the food factors of the so-called mosquito-destroying fishes of Bengal.—*Panchax-panchax*, *Barbus stigma*, *Esomus danricus* and *Trichogaster fasciatus*," *Curr. Sci.*, 1937, **5**, (7), 357–61.

Thapar, G. S. .. .. "On *Acanthogyrus*, n. g., from the intestine of the Indian fish *Labeo rohita*, with a note on the classification of the Acanthocephala," *Jour. Helminthol.*, 1927, **5**, 109–20.

Van Cleave, H. J. .. .. "Notes on the life-cycle of two species of Acanthocephala from *fresh-water* fishes," *Jour. Parasitol.*, 1920, **6**, 167–72.

Idem .. .. .. "A key to the genera of Acanthocephala," *Trans. Amer. Micr. Soc.*, 1923, **42**, 184–91.

———— .. .. "Two new genera and species of Acanthocephala from fishes of India," *Rec. Ind. Mus.*, 1928, **30**, 147–49.

Varma, S. C., & Datta, M. N. "Acanthocephala from Northern India.—I. A new genus *Acanthosentis* from a Calcutta fish," *Ann. Trop. Med. Parasit.*, 1929, **23**, 483–500.

EXPLANATION OF FIGURES.

(All Camera Lucida Drawings.)

FIG. 1.—Lateral view of a male *Acanthosentis holospinus* sp. nov. showing the morphological characters.

FIG. 2A.—Proboscis of *A. holospinus* sp. nov. showing the arrangement and nature of hooks.

FIG. 2B.—Body spines of *A. holospinus* sp. nov., highly magnified.

FIG. 3.—Female genitalia of *A. holospinus* sp. nov.

FIG. 4.—*A. holospinus* sp. nov. in copulation.

ABBREVIATIONS USED.

b.—bursa ; *b.n.*—body nucleus ; *b.s.*—body spines ; *e.m.*—egg mass ; *g.c.*—guard cells ; *l.*—lemnisci ; *n.g.*—nerve ganglion ; *p.*—proboscis ; *p.d.*—prostatic duct ; *p.g.*—prostatic gland ; *p.h.*—proboscis hook ; *p.s.*—proboscis sheath ; *s.v.*—seminal vesicle ; *t.*—testes ; *u.*—uterus ; *u.b.*—uterine bell ; *v.*—vagina ; *v.d.*—vas deferens ; *v.g.*—vaginal gland.

ON THE SCHIZOGONIC FORMS OF A PLASMODID FOUND IN THE BLOOD OF THE GREEN SNAKE *PASSERITA MYCTERIZANS* DAUD.

By Prof. Col. I. Froilano de Mello
and
Luis da Fonseca.
(*Medical College, Nova-Góa.*)

Received December 20, 1937.

Some specimens of this snake have been in past years examined by the senior author, without being able to detect any blood parasite. This year, however, in one specimen collected by one of us (L. da Fonseca) at Sto Estevam, and kindly identified by Dr. S. L. Hora, from the Zoological Survey of India, Calcutta, a scanty infection was seen by a very small blood parasite, which at first seemed to us to belong to some genus of the Piroplasmids. The discovery of the pigment in the schizonts could soon settle this point and the parasite was definitely classified as a Plasmodid.

We were not fortunate enough to see any form which could give evidence of being a gametocyte : hence, our statements are limited only to the description of the Schizogonic forms of this Plasmodid.

The coloured plate which illustrates this paper gives an idea of the morphology of the parasite. Some points, however, must be emphasized : (*a*) the minute pyriform (Fig. 7) or amœboid (Fig. 5) schizonts, devoid of pigment, which may even be absent in larger roundish forms (Fig. 2) ; the ring form, with the protoplasm very compact (Figs. 1 and 3) or more or less vacuolated (Figs. 4 and 6) with small dots of brownish pigment scattered all over the body.

The following phases of multiplication were found : the chromatin divided into two, three and four granules, this number seeming the ultimate phase of the multiplication process. Particularly interesting is the crucial multiplication depicted in our (Fig. 11), remembering similar figures in some genera of Piroplasmids.

The red cell did not show any alteration.

The measurements of the parasite vary between one to three microns, the rosettes having three to four microns.

The slides were stained by Leishmann's stain and by May-Grunwald Giemsa. The staining by iron hæmatoxyline did not prove useful for this study.

No parasite has yet been described in this snake. Our records are, therefore, the first and the parasite will be named *Plasmodium passeritæ* sp. n.

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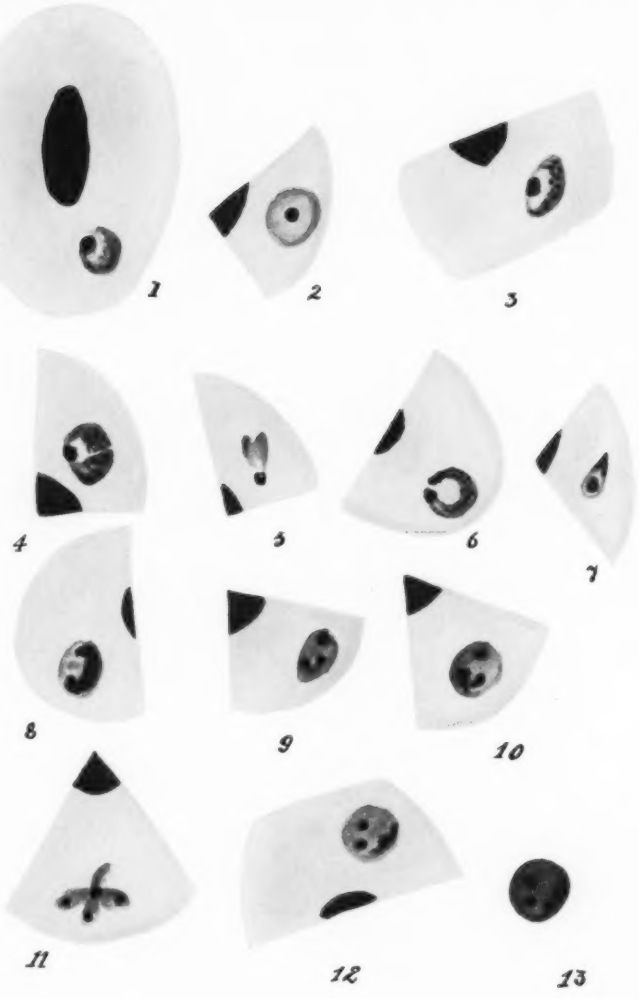

Plasmodium passeritæ sp. n.

PARASITES OF THE GENUS *BERTARELLIA* IN THE BLOOD OF THE TORTOISES OF INDIA AND BRAZIL.

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(Communicated by Colonel I. Froilano de Mello.)

In a previous paper presented to the Indian Academy of Sciences[1] we have described a parasite of the genus *Bertarellia* and pointed out the reason why this designation should be maintained in the protozoological nomenclature.

The present note deals with a similar parasite found in the blood of the Indian tortoise *Emyda granosa*. Almost identical to *Bertarellia calotis* with some slight differences which will be stated in the course of this description, it is seen, in blood films stained by Leishmann or May-Grunwald-Giemsa, taking always a violet chromatic coloration in its different forms, which may be roundish (62%), elliptical (37%), and seldom oval, piriform, ring-like, etc.

The violet tone is noticed only in the part which we consider to be the chromatic part of the parasite. Rarely such chromatic point, of an anaplasmoid nature, is the only structure inside the cytoplasm of the red cell; but, in general, such chromatic point is surrounded by a clear halo, often very difficult to be distinguished, and extremely polymorphous; roundish or elliptic, complete or incomplete, narrow or fairly large. The situation of the parasite in the interior of the red cell varies differently, being sometimes central, sometimes polar and rarely peripheric, this one suggesting a beginning of the invasion of the erythrocyte.

The red cell may contain more than one parasite and often one of these haloes may show more than one chromatic point suggesting a binary division of the parasite. We have been able to see even three chromatic granules closely attached to one another. Such binary division is not always equal as the buds have not always the same size nor stain with the same intensity: generally, the larger buds are more siderophyl than the small ones.

Forms entirely similar to those invading the red cells have also been found free in the plasma.

The *Bertarellia* of this tortoise has never shown the blue coloration of the protoplasm which was figured by us in *Bertarellia calotis*: this is the only difference between the two.

The staining by the iron hematoxylin of Heidenhain did not give any further detail.

FIG. 1.
Bertarellia of *Emyda granosa*.

Our Fig. 1 shows the different forms of the parasite.

* * * *

In our previous paper we have made reference to a statement of Prof. A. Carini from S. Paulo, Brazil, on this genus of parasites. The same professor having sent to us two blood films of Brazilian tortoises, one from 1933, the other from 1937, both coloured by Romanowsky stain, we had opportunity of examining them with greatest care. That of 1933 belongs to the tortoise *Chelonea midas* and shows two kinds of parasites: (*a*) one *Tunetella*, in great quantity, (*b*) one *Bertarellia*. That of 1937 belongs to

the tortoise *Caretta-caretta* and shows both *Tunetella* an *Bertarellia* in almost equal number.

The forms of *Bertarellia* observed in these films are entirely similar, as well in structure as in size and stain to those found in *Emyda granosa* and we are convinced that there is no difference between the *Bertarellia* of the Indian and the Brazilian tortoises of Prof. Carini.

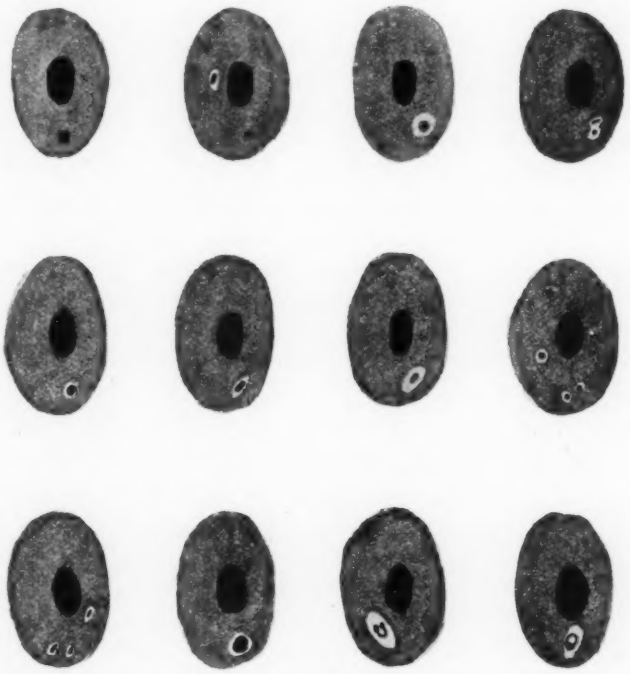

FIG. 2.
Bertarellia of Brazilian tortoises.

Fig. 2 represents the forms found in the films of Prof. Carini.

The genus *Tunetella* has been created by Brumpt and Lavier[2] for a kind of piroplasmide described by the French authors in the blood of Tunisian tortoise, *Emys leprosa*, brought at Paris.

They state that " les petites formes de cette dernière évoquent ce qu'a decrit Carini (1930) pour sa *Bertarellia leptodactyli*, parasites de globules rouges de l'Amphibien, *Leptodactylus ocellatus* ". They state also their affinities with the *Dactylosoma* of Amphibians whose schizogony, easily

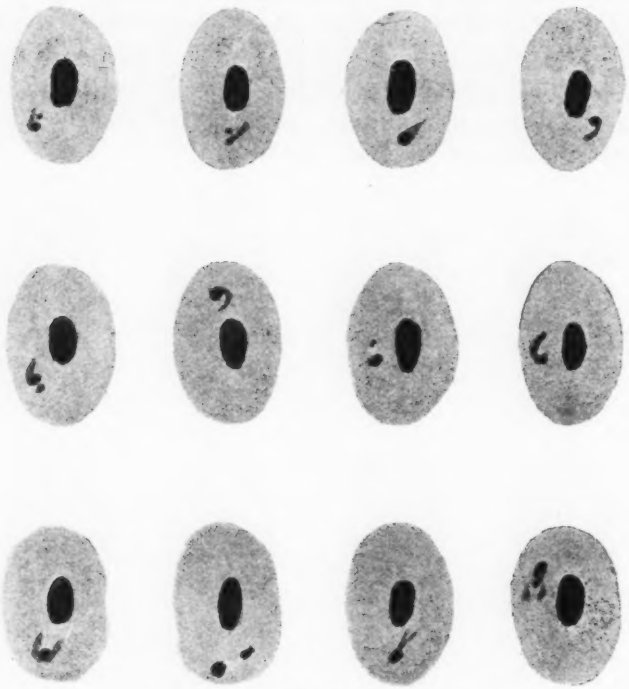

FIG. 3.
Tunetellas of the Brazilian tortoises.

observed in peripheral blood, and tinctorial reactions seem to us enough differential characters between both these genera.

The parasite of Brumpt and Lavier which was named *Tunetella Emydis* n. g. n. sp. shows in its largest form the aspect of a more or less regular ring of 2 to 5 microns of diam. ; cytoplasm violet bluish, containing 1 to 3 purple chromatic granules, surrounding a clear centre. The parasite may show oval, elongated, piriform, lobulated (amœboid) appearance ; often 1 or 2 little expansions suggest a kind of pseudopods (their Figs. 15 and 16). Small parasites of less than one micron of diam., isolated or in groups simulating rosettes or in a rather linear disposition, are to be found, some with a distinct chromatic point, others without such granules and appearing as basophyl spots of a grey bluish coloration. The authors believe that such spots belong certainly to the same parasite "caril est fréquent de les voir associées à des petites formes d'aspect caractéristique ; leur signification cependant ne nous apparaît pas très clairement : il peut s'agir d'un aspect artificiel dû à une

fragilité toute spéciale du cytoplasme parasitaire que la pression du frottis aurait fragmenté en plusieurs éléments ; mais il peut s'agir aussi d'un stade de multiplication active aboutissant à de toutes petites formes susceptibles de porter l'infection dans d'autres globules ; en faveur de cette vue parle le fait qu'on peut rencontrer certains de ces éléments isolés ; contre elle, leur chromophilie, beaucoup plus faible que celles des formes anaplasmoides dont l'existence est connue dans le cycle évolutif de divers hématozoaires."

The forms of *Tunetella* which we have found in the films of Prof. Carini may be differentiated from *Bertarellia* first of all because they are never surrounded by the clear halo which we found generally in *Bertarellia* ; secondly, because their nucleus is much darker than those of *Bertarellia* even when it is divided and the bud of the division is quite separated from the mother nucleus. This nucleus is generally followed by a protoplasmic expansion under the form of a rod, or coma, staining light greyish. Often such expansions are completely separated of the main body and do not show any chromatic point, corresponding thus to the basophyl spot described by the French authors. Sometimes the nucleus is situated in the middle of a protoplasmic band curved under the form of a U, sometimes at the vertex of a Y. In some forms the nuclear buds are separated by a clear zone of protoplasm.

Fig. 3 shows the different aspects of these *Tunetellas* which we are not able to classify specifically ; however they seem to us somewhat different from *Tunetella Emydis* Brumpt and Lavier, 1935.

* * * *

The three specimens of *Bertarellia* found in *Emyda granosa*, *Chelonia midas* and *Caretta-caretta* seem to us to belong to the same species which, as it has already been stated, is different from *Bertarellia calotis*.

As the parasite has been found in three different genera of tortoises, we will name it *Bertarellia carinii* n. sp.

BIBLIOGRAPHY.

[1] de Mello, I. Froilano, and de Meyrelles, Caetano Corrêa, "On the nature and identification of some roundish bodies found either free or as endoglobular parasites in the blood of *Calotes versicolor* Daud, subspecies *major* Blyth," *Proc. Ind. Acad. Sci.*, 1937, 6, 2.

[2] Brumpt, E., et Lavier, G., "Sur un piroplasmidé nouveau, parasite de tortue *Tunetella emydis* n. g. n. sp.," *Ann. Parasit. Hum. et Compar.*, 1935, T. 13, 5.

THE TREMATODE GENUS *ALLOCREADIUM* IN NORTH INDIAN FRESH-WATER FISHES.*

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Received October 20, 1937.

(Communicated by Prof. C. R. Narayan Rao, M.A.)

The description of *Allocreadium handiai*—the first member of this genus reported from an Indian fresh-water fish, *Ophiocephalus punctatus*, has been dealt with in another paper (Pande, 1937). In this communication is given a description of two new species of *Allocreadium* obtained from *Gobius guiris* and *Barbus chilinoides* in the course of the studies on digenetic trematodes of various fresh-water fishes examined at Allahabad and Almora.

Historical Review of the Genus Allocreadium.

The type species of this genus was originally recorded by Looss (1894) as *Distomum isoporum* and was later placed with *Distomum angusticolle* Hausmann (1896) in a new genus *Creadium* (1899) which name was later changed by him to *Allocreadium* in 1900. Since then the inclusion of a large number of species under this genus has been proposed by Odhner (1901), Stossich (1906), Linton (1908) and Wallin (1909). For some of these species, new genera were created by Odhner (1902, 1905) and Nicoll (1909). The latter author also pointed out in the same paper the systematic position of certain other species described by Stossich near some of his newly created genera. The remaining species of *Allocreadium* after this grouping are :— *A. isoporum*, *A. angusticolle*, *A. transversale* Rudolphi, *A. pallens* Rud., *A. lobatum* Wallin, *A. colligatum* Wallin (later removed from *Allocreadium* by Nicoll in 1915) and *A. dubium* Stossich. Subsequently to this date the descriptions of other species found in the literature are :— *A. annandalei* Southwell (1913), *A. fowleri* Leiper and Atkinson (1914), *A. pisacanthi* Mac Callum (1921), *A. hasu* and *A. japonicum* Ozaki (1926)—both having been redescribed by Yamaguti (1934), *A. ictaluri* and *A. beleosomi* Pearse (1928), *A. halli* Mueller and van Cleave (1932), *A. polymorphum* Layman (1933), *A. psuedotritoni* Rankin (1937) and *A. handiai* Pande (1937). Van Cleave and Mueller (1934) came to the conclusion that *A. halli* and *A. ictaluri* represent one and the same species. For these two species Arnold (1934) had created a new genus *Polylekithum*. The differences between the latter genus and *Allocreadium*

* A part of the work done while a D.Sc. scholar of the University of Allahabad.

have not been regarded of more than specific value by the present author in his previous paper and consequently the only species, *P. ictaluri* (syn. *A. ictaluri*), has been transferred back to *Allocreadium*. The descriptions of *A. annandalei*, *A. fowleri* and *A. pisancanthi* being inadequate, these species are treated as *species inquirendæ*. It is not possible to assign them to their proper generic rank particularly in view of the large number of closely related genera known in the sub-family Allocreadiinæ—a consideration of which is beyond the scope of this paper. Moreover, the account of *A. fowleri* given by Leiper and Atkinson deals with immature specimens.

The author is greatly indebted to Dr. H. R. Mehra, under whose direction this work was undertaken, for his many valuable suggestions; and to Dr. D. R. Bhattacharya for the facilities provided in the Department.

Allocreadium nicolli n. sp. (Figs. 1 and 2).

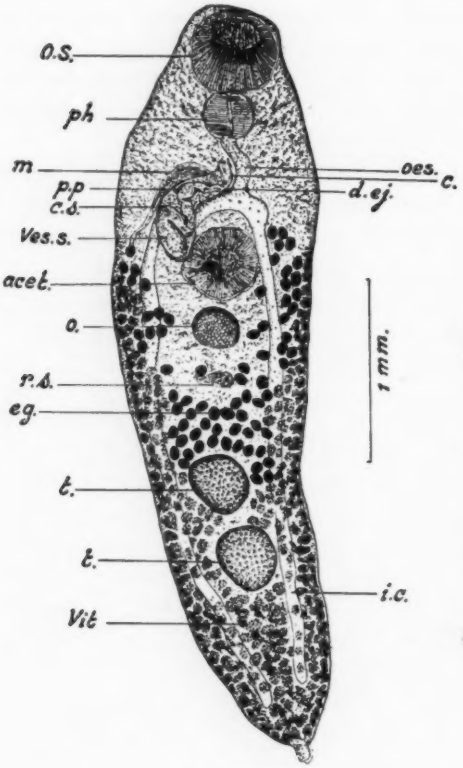
Host—*Gobius guiris*.

Position—Small intestine.

Locality—Allahabad.

Description.—Body elongated, thick and plump, somewhat rounded at anterior and pointed at posterior ends, narrow in posterior half, measuring 4–4·2 in length and 1·1 in maximum breadth which lies in the neighbourhood of the acetabulum. Cuticle thick and aspinose. Oral sucker sub-terminal, 0·45–0·46 × 0·43–0·48 in size, larger than acetabulum; pre-pharynx present; pharynx large 0·18–0·22 × 0·25–0·28 in size; œsophagus 0·36 in length, slightly curved in contracted specimens; intestinal bifurcation close to dorsal surface, situated a little in front of acetabulum; cæca running back dorsally near lateral body margins, ending about one-fourth of post-testicular space in front of hinder extremity. Sub-cuticular unicellular glands more conspicuously developed in pre-acetubular part of body. Acetabulum, 0·36–0·4 in diameter, situated at anterior third of body. Genital pore median, leading into a short and narrow atrium with male and female ducts opening into it dorsally, lies immediately below intestinal bifurcation. Excretory pore terminal, near dorsal surface, leading through short thick walled duct to tubulur bladder; excretory bladder close to dorsal body wall, extending anteriorly to inter-testicular space and receiving the two collecting ducts a little behind its anterior end. Testis nearly spherical and equal in size, behind one another, in posterior body half with a small space between them; anterior testis, slightly sinistral, 0·32–0·34 × 0·28–0·3 in size, situated at about 0·5 distance behind equator of body; posterior testis, slightly dextral or median, 0·3–0·34 in diameter, at middle of posterior body half. Cirrus sac elongated, curved round anterior half of

acetabulum, extending posteriorly near its centre, placed only slightly off the median line in its posterior half; vesicula seminalis much coiled in basal half; pars prostatica spherical; ductus ejaculatorius slightly convoluted;



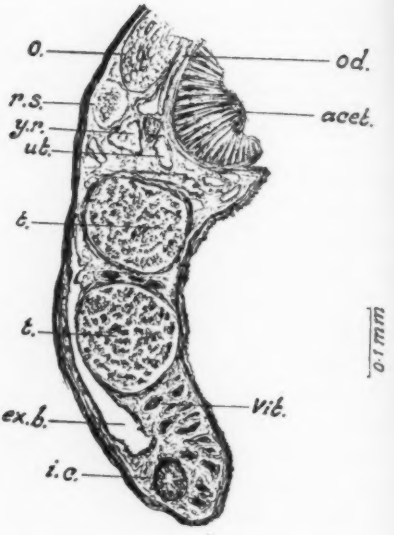


Fig. 1. Fig. 2.

Fig. 1. *Allocreadium nicolli* n. sp.—dorsal view.

Fig. 2. Sagittal section through post-acetabular region of body of *A. nicolli* showing anterior extent of excretory bladder.

Key to lettering used in figures :—*acet.*—acetabulum; *c.*—cirrus; *c. s.*—cirrus sac; *d.ej.*—ductus ejaculatorius; *eg.*—eggs; *ex.b.*—excretory bladder; *i.c.*—intestinal cæcum; *m.*—metraterm; *o.*—ovary; *od.*—oviduct; *oes.*—oesophagus; *o.s.*—oral sucker; *ph.*—pharynx; *p.p.*—pars prostatica; *r.s.*—receptaculum seminis; *t.*—testis; *ut.*—uterus; *ves.s.*—vesicula seminalis; *vit.*—vitellaria; *y.r.*—yolk-reservoir.

prostate gland cells surrounding distal coils of vesicula seminalis, pars prostatica and ejaculatory duct. Ovary nearly globular, median, dorsal, 0·22–0·23 × 0·23–0·25 in dimensions and situated close behind acetabulum—

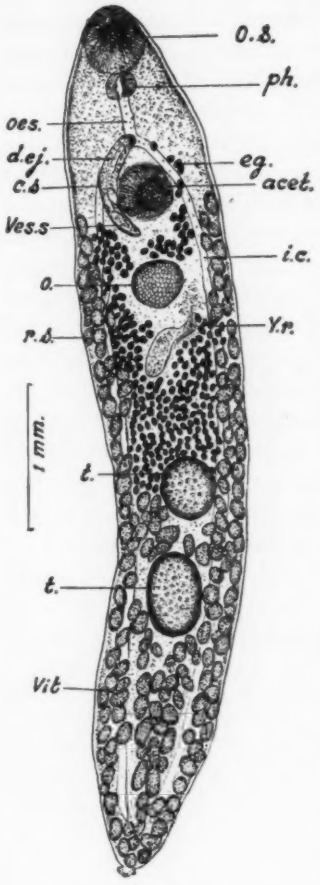


FIG. 3.
Allocreadium kosia n. sp.
dorsal view.

in contracted specimens above posterior half of latter; oviduct arising ventrally near middle of ovary; receptaculum seminis 0·11 × 0·23 in size, post-ovarian, placed transversely to body length at middle of body close to dorsal body wall; the short and nearly straight Laurer's canal, after its origin, winds posteriorly to open on the dorsal surface behind acetabulum; shell gland mass situated posteroventrally to hinder margin of ovary slightly lateral to median line; transverse vitelline duct and yolk-reservoir just below receptaculum seminis; descending coils of uterus after origin from shell gland mass, filling up inter-cæcal space between receptaculum seminis and anterior testis with coils extending back in convoluted course as far as middle of anterior testis situated dorsally and laterally to it; ascending limb of uterus in front of receptaculum seminis ventral to ovary and intestinal cæca but dorso-lateral to acetabulum opening into well-developed metraterm; metraterm lying parallel to terminal half of cirrus sac; ripe eggs yellowish, measuring 0·072 × 0·054 in size; vitelline follicles commencing anteriorly from near anterior margin of acetabulum, mostly lateral and ventral to intestinal cæca, but extending inwards between testes and filling entire inter-cæcal space behind posterior testis with follicles lying ventral to cæca and excretory bladder in this part of body.

Remarks.—The proposed new species *A. nicolli* agrees with *A. isoporum*, *A. transversale*, *A. pallens*, *A. lobatum*, *A. hasu*, *A. japonicum*, *A. beleosomi* and *A. handiai* in that the vitellaria do not extend anterior to the acetabulum. The type species, *A. isoporum*, is easily distinguished from it in a number of features such as the ratio of the suckers, anterior extent of the excretory bladder (excretory bladder reaching to hinder margin of posterior testis in *isoporum*), position of the receptaculum seminis in relation to the ovary (in *isoporum* ovary is on the right side and receptaculum seminis in level

with it), posterior extent of the uterus, anterior extension of vitelline follicles (in *isoporum* the vitellaria do not reach the posterior level of acetabulum), length of eggs and their number in the uterus. From *A. transversale* and *A. pallens* the new species differs in the ratio of suckers (acetabulum is one and a half times larger than oral sucker in *transversale* and twice as large as oral sucker in *pallens*). *A. lobatum* differs from *A. nicolli* n.sp. in the equal size of the two suckers, position of its acetabulum in the posterior part of the first fourth of the body, excretory bladder reaching to the posterior testis, lobed nature of the testes, the vitellaria reaching anteriorly to the level of the ovary, posterior extent of the uterus (uterus fills up the space between the anterior testis and the acetabulum in *labatum*) and the presence of numerous eggs. *A. hasu* can be separated from the new species on account of the acetabulum being much larger than the oral sucker, uterus coiled between anterior testis and acetabulum, and the excretory bladder extending anteriorly midway between the posterior testis and the hinder extremity of the body. *A. japonicum* also differs from it in the acetabulum being larger than the oral sucker. From *A. beleosomi* the new species is distinguished by the difference in the ratio of the suckers (oral sucker is slightly more than half the acetabulum in *beleosomi*), presence of a prepharynx, length of the œsophagus, position of the acetabulum (acetabulum situated at anterior fourth of body length in *beleosomi*), position of the ovary (in *beleosomi* ovary lies immediately in front of anterior testis), position of the uterus (between the ovary and the acetabulum in *beleosomi*) and size of the eggs. *A. handiai* differs from it among other characters in the position of the genital pore posterior to the intestinal fork and the extent of the cirrus sac.

Allocreadium kosia n. sp. (Fig. 3).

Host—*Barbus chilinoides*.

Position—Small intestine.

Locality—Almora ; Kumaon Hills.

Description.—Body elongated, flattened behind acetabular level and cylindrical in front, with bluntly pointed ends, length 6, breadth 1–1·1, nearly uniform. Oral sucker subterminal 0·43 × 0·41 in size ; prepharynx present ; pharynx 0·18 × 0·2 in size ; œsophagus 0·28–0·33 long ; intestinal bifurcation some distance in front of acetabulum ; cæca terminating a short distance in front of hinder end. Subcuticular gland cells predominantly developed in body parenchyma. Acetabulum slightly smaller than oral sucker, 0·38–0·39 in diameter, situated in posterior part of first quarter of body. Genital pore, leading into a small and narrow atrium, lies just below intestinal bifurcation. Excretory pore terminal, median ; excretory bladder

extending anteriorly nearly midway between posterior testis and hinder end of body. Testes tandem, median, in third quarter of body; anterior testis nearly spherical, 0·4–0·45 × 0·38–0·4 in size, situated just behind middle of body; posterior testis ellipsoidal, 0·55 × 0·38 in size, situated 0·2 distance behind anterior testis. Cirrus sac curved in a crescent-shaped manner around acetabulum on its left side and extending posteriorly slightly beyond its hinder margin; vesicula seminalis coiled; pars prossalica spherical, continuing into a nearly straight ejaculatory duct. Ovary median, dorsal, nearly pear-shaped, situated at one-third of body length from anterior end, 0·31 × 0·36 in size; shell gland mass immediately postero-lateral to ovary; receptaculum siminis elongated, 0·4 × 0·14 in size, obliquely placed just behind ovary under dorsal body wall; the short Laurer's canal, the narrow duct of the receptaculum seminis, and the duct from the yolk reservoir, situated close underneath the dorsal body wall, run together towards the shell gland mass; uterine coils between acetabulum and anterior testis in intercæcal space with coils extending laterally to middle of anterior testis; ripe eggs brownish, measuring 0·072–0·075 × 0·054–0·057 in size; vitellaria extend laterally from middle of acetabulum to posterior tip of body, follicles meeting in intercæcal space between testes and behind posterior testis.

Remarks.—Among the species of *Allocreadium* characterised by the vitellaria not extending anteriorly beyond the anterior limits of the acetabulum the new species is closely related to *A. hasu* on account of the anterior extent of the excretory bladder and the vitellaria. But it differs from it in the position of the acetabulum, greater length of the posterior testis, and the extent of the cirrus sac and the uterus.

REFERENCES.

Arnold, J. G. (Jr.) .. .. .. *Trans. Amer. Micros. Soc.*, 1934, **53**, 267.

Layman, E. M. .. .. .. *Trav. St. Limnol. Lac Bajkal*, Lenningrad, 1933, **4**, 74.

Leiper, R. T., and Atkinson, E. L. .. *Proc. Zool. Soc., London*, 1914, 224.

Looss, A. .. .. .. *Bibl. Zool.*, 1894, Heft 16.

———— .. .. .. *Zool. Jahrb. Syst.*, 1899, **12**.

———— .. .. .. *Zool. Anz.*, 1900, **23**, 602.

Lühe, M. .. .. *Süsswasserfauna Deutschlands*, 1909, Heft **17**, 53.

MacCallum, G. A. .. .. .. *Zoopathologica*, 1921, **1**, 149.

Mueller, J. F. .. .. .. *Roos. Wild Life Ann.*, 1934, **3**, 368.

————, and Van Cleave, H. J. .. *Ibid.*, 1932, **3**, 88.

Nicoll, W. .. .. .. *Quar. Jour. Micr. Sci.*, 1909, **53**, 391.

———— .. .. .. *Parasit.*, 1910, **3**, 322.

———— .. .. .. *Ibid.*, 1915, **7**, 339.

Odhner, T. .. .. .. *Zool. Jahrb. Syst.*, 1901, **14**, 483.
———— .. .. .. *Central Bakt. Par.*, 1902, **31**, 152.
———— .. .. .. *Fauna Arctica*, 1905, **4**, 291.
Pande, B. P. .. .. .. *Ann. Mag. Nat. Hist.*, 1937, **20**, 415.
Pearse, A. S. .. .. .. *Trans. Wis. Aca. Sci., Arts and Letters*, 1924, **21**, 147.
Rankin, J. S. (Jr.) .. .. *Jour. Parasit.*, 1937, **23**, 33.
Southwell, M. .. .. .. *Notes from Bengal Fisheries Lab., Ind. Mus.*, 1913, **1**, 98.
Stossich, M. .. .. .. *Boll. Soc. Adriat.*, 1906, **22**, 211.
Van Cleave, H. J., and Mueller, J. F. *Roos. Wild Life Ann.*, 1934, **3**, 198.
Wallin, I. E. .. .. .. *Stud. Zool. Lab. Univ. Neb.*, 1909, **95**, 50.
Ward, H. B., and Whipple, G. C. .. *Fresh Water Biology*, 1918, 394.
Yamaguti, S. .. .. .. *Jap. Jour. Zool.*, 1934, **5**, 281.

All measurements in millimetres.

HISTOLOGY OF THE DIGESTIVE TRACT OF *SACCOBRANCHUS FOSSILIS* AND *MACRONES VITTATUS*.

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Introduction.

This paper deals with the histology of the digestive tract of two Siluroid fishes, *Saccobranchus fossilis* and *Macrones vittatus*. The paper is based on studies of sections with details of gross anatomy from fresh material. Particular attention is given to the epithelium of the different regions of the digestive tract, since they exhibit many variations.

Bouin's fluid was used exclusively for fixation. The usual method of paraffin-wax embedding was employed for cutting sections. The stains used were Hæmalum and hæmatoxylin with eosin as a cytoplasmic stain. In some cases Mallory's triple and Pascini's stains were used.

The work was undertaken at the suggestion of Prof. C. R. Narayan Rao, and carried out under his direction. I am much indebted to him for his suggestions and encouragement shown during the course of the work. I am thankful to Mr. A. Narayan Rao, for his guidance and to Asst. Prof. B. R. Seshachar, and Mr. L. S. Ramaswamy, for the supply of required materials.

I am grateful to the University authorities and to Prof. C. R. Narayan Rao, Offg. Principal, Central College, Bangalore, for having given permission to publish the thesis. My appreciations are also due to Mr. S. Jayarama Sarma, for having made the drawings.

Historical.

It is quite impossible in a short historical account to do justice to the work that has been carried out on the structure of the digestive tract of fishes. Agassiz and Vogt in 1845 worked on the stomach of the trouts. Later, in 1861, Valatour worked on Teleost fishes.

During the current century, the results of four prominent researchers are on record ; those of Greene on King Salmon (1912), of Ben Dawes on the alimentary tract of Plaice (1929), a detailed paper by Irving, H. Blake on the histology of the digestive tract of the Sea Bass (1930), and a full account on the digestive tract of Minnow (1931), by Mary Dora Rogick. The literature is indeed limited on this subject from the view-point of modern technique employed in histological investigation.

General Morphological Notes.

The alimentary tract of *Saccobranchus fossilis* is not a uniform straight tube throughout, but is thrown into a large number of folds. It is only partially differentiated into regions of which the following can be recognised in addition to buccal cavity and pharynx : œsophagus, stomach and intestine. The buccal cavity and pharynx can be seen when that part of the digestive tube is cut open. The buccal cavity is narrow in front and becomes wide posteriorly. It extends from the lips up to the first pair of gill-slits. The pharyngeal cavity includes the branchial region, as well as the region of the pharyngeal teeth. It is wider in front and narrows down posteriorly. The œsophagus is in the form of a short tube, of a greater calibre in front and where it joins the stomach it becomes narrow. There is a slight external indication of the passage of œsophagus into the stomach, but if it is cut open, the line of demarcation is well marked off, the stomach folds appear distinctly different from those of œsophagus.

The stomach is a U-shaped organ and its greatest diameter is at the middle of its length, posterior to which it becomes more slender especially near the pyloric sphincter. A part of the sphincter projects into the lumen of the intestine.

The intestine is much convoluted (except the terminal portion—the rectal—which follows a straight course to the anus) and is held in position by the mesentery.

The pneumatic duct comes and joins the posterior part of the œsophagus. The bile and the pancreatic ducts enter the anterior part of the intestine just near the pyloric region of the stomach.

The digestive tract is supplied with pure blood from a branch of the dorsal aorta. The hepatic portal vein is found distributed in the mesentery of the intestine and stomach. From the stomach the hepatic vein joins the liver. This part is innervated by a branch of the vagus.

Although the lengths of the different regions of the alimentary tract are generally subject to considerable variation, the following carefully made measurements of the series in a single fish, 18·5 cm. long, will convey some idea of their order.

	cm.
Length of the whole tract coiled from lips to anus ..	6·8
Lips to the posterior margin of pharyngeal teeth ..	2·1
Length of the œsophagus	0·8
Anterior end of stomach to pyloric sphincter ..	1·0
From pyloric sphincter up to anus coiled ..	3·8
Length of the intestine uncoiled	17·8

1. *Lips.*

The lip consists peripherally of a stratified epithelium and beneath this a sub-epithelial connective tissue. The stratified epithelium has mucous cells and taste buds towards its free surface and closely packed undifferentiated columnar cells towards the sub-epithelial connective tissue. A basement membrane and a stratum compactum are not found though the compactly arranged connective tissue fibres below the undifferentiated cells stimulate the presence of a stratum compactum (Plate VII, Fig. 1 A).

Epithelium.—The mucous cells are either elongated or oval and they are arranged with their long axis perpendicular to the surface of the epithelium. Those that open to the exterior are goblet-shaped. They exhibit a reticular appearance and the meshes are filled with a granular substance. Each mucous cell has a basal nucleus which is spherical usually or flattened occasionally and consists of a single heavily stained nucleolus with some lightly stained chromatin granules. The mucous cells are derived from the undifferentiated cells and as such the different stages could be made out throughout the thickness of the epithelium (Plate VII, Fig. 1 B).

Taste buds which occupy the whole thickness of the epithelium are located on the summits of the connective tissue papillæ. They are spindle shaped and consist of elongated cells with their nuclei situated more towards their base than towards their centre. The nuclei are oval in form and

contain heavily stained chromatin granules. The nucleolus cannot be made out. From the structure of the nucleus it can be inferred that the taste buds are composed of modified undifferentiated cells of the epithelium. The free surface of the taste bud is generally sunk giving the appearance of a gustatory pore (Plate VII, Fig. 1 B).

The undifferentiated cells are columnar towards their bases and taper into points towards their distal ends. The nuclei are generally oval in shape while some are spherical. Each nucleus consists of chromatin granules which react differently to one and the same stain. In some the nucleoli can be made out with difficulty.

Sub-epithelial connective tissue.—The sub-epithelial connective tissue could be divided into a compactly arranged region beneath the epithelium and a loosely arranged mesh-work of fibres which are vascularised and innervated. There are pigment bodies here and there (Plate VII, Fig. 1 B).

2. *Buccal Cavity.*

The buccal wall consists of a stratified epithelium of about ten to twelve cells thick and sub-epithelial connective tissue beneath it. The epithelium is composed of mucous cells and taste buds towards its free surface and undifferentiated cells towards the base. Besides these, there are certain big cells conspicuous by their one or more nuclei situated here and there in the thickness of the epithelium (giant cells). There are certain bodies of variable shapes which take up dark stain with hæmatoxylin and are found in the basal region of the epithelium (Plate VIII).

Epithelium.—The mucus cells are oval in shape and a majority of them open to the buccal cavity. When they do not do so, they are spherical in appearance. The cytoplasm of these cells is reticulate in structure. The nucleus which is found usually at the base of each cell is either spherical or flattened. Each nucleus has a single conspicuous nucleolus (Plate VIII, Fig. 2 B).

The taste buds are very like those found in the lips. The connective tissue papillæ on which the taste buds are situated are not as conspicuous and elevated as in the lips. The gustatory pore is prominent. The free ends of the cells are heavily stained and on examination with a high power of the microscope reveal highly refracting granules comparable to the hairlets of the same organ in mammals.

Some of the undifferentiated cells are columnar while others are roughly spherical. Their cell outlines cannot be made out very distinctly. The nuclei of these cells are of two types. Some are lightly stained, bigger in size, with a conspicuous nucleolus, while others are heavily stained, smaller

in size, sometimes with one nucleolus, which can be made out with some difficulty (Plate VIII, Fig. 2 B).

The cytoplasm of the big cells found in the thickness of the epithelium is finely granular and contain from one to four nuclei ; usually these cells contain a clearer region in the centre which is probably the nuclear area after the disappearance of the nuclear membrane. The carefully made measurements of two typical cells, one with four nuclei and another with a single nucleus, are given below. The former measures 29 microns along its long axis and 25 microns along its short axis. The diameter of the clear space is 12 microns. The diameter of each nucleus is ablout 2 to 3 microns. The latter measures 30 microns along its long axis and 16 microns along its short axis, while the diameter of the single nucleus is 4 microns. From the above data it can be inferred that these cells are dividing. The cell cytoplasm does not divide with the division of the nucleus but is delayed till another division of the daughter nuclei takes place. The size of the cell is in conformity with this view. Later the cytoplasm divides, each part getting its share of nucleus. The structure of the daughter cells and their nuclei are very like that of the undifferentiated cells of the spherical type with a smaller heavily stained nucleus. From the similarity of the structure of these two types it can be inferred that the former are derived from the latter. In fact, the similarity between these nuclei and those found at the base of the mucous cells reveal the view that those large cells divide and their daughter cells gradually metamorphose themselves to form mucus cells.

Sub-epithelial connective tissue.—This region of the buccal wall can be divided into two regions as in the lips. The compactly arranged connective tissue fibres differ from the same structure of the lips by the presence of nuclei which is in all probability that of connective tissue cells though cells as such cannot be made out. The remaining part of the connective tissue differs from that of the lips in having a very loose mesh-work with blood vessels and capillaries.

3. *Pharynx.*

The pharyngeal wall can be structurally divided into anterior and posterior regions. The former comprises the branchial region and the latter forms the pharyngeal dental portion. The anterior part is characterised by the absence of masculature and the epithelium is not thrown into folds ; on the other hand, the posterior part is thrown into folds and the masculature is complicated by the inclusion of oblique muscles. The posterior part is also marked by the presence of teeth, the structure of which is dealt with under a separate heading.

(*a*) *Anterior pharyngeal region.*—The pharyngeal wall consists of a stratified epithelium and beneath it the sub-epithelial connective tissue (Plate IX).

Epithelium.—The epithelium of this region, in regard to details of histological structure, is very like that of the buccal epithelium. It is thrown into a few folds. The summit of the folds sometimes contains a taste bud. The mucous cells are found at the base of the crypts; in some specimens they are found arranged in a single row peripherally as seen in the illustration (Plate IX).

Sub-epithelial connective tissue.—This region can be differentiated into two parts. That part which is next to the epithelium consists of a closer network and is well vascularised. Beneath this is areolar connective tissue of a very loose texture. The interstices of the mesh-work is probably filled up by fat cells.

(*b*) *Posterior pharyngeal region.*—The pharyngeal wall in this region has stratified epithelium, sub-epithelial connective tissue and mascularis (Plate X).

Epithelium.—The epithelium is composed of mucous cells, taste buds and undifferentiated cells which are actively dividing.

The mucous cells are generally arranged superficially in one or two layers and are located in the side walls of the crypts. Those that are found near the surface are generally bigger than those lying beneath them. The cells that open into the pharyngeal lumen are either vase or goblet-shaped. On a minute examination, their interior reveals a reticulate structure. Sometimes the contents occur in a frothy condition lying on the free surface of the epithelium. Hence the reticulate structure of the cell must be the sectional view of mucus. The nucleus is found at the base and in some cells it is stained heavily. The distal part of the nucleus, which is applied to the base of the mucous cell, is like that of a shallow cup and the opposite end is drawn out into a tapering point. The mucous cells of the second layer are either spherical or oval with a basal nucleus. The clear spaces of these cells are in all probability in the nature of vacuoles which reach an enormous size as the quantity of mucus in them increases. When they are full of mucus, their distal ends reach the surface and burst discharging the contents into the lumen (Plate X).

The structure of the taste buds occurring in this region is similar to that of the same organs in buccal epithelium. They are however few in number.

The undifferentiated cells occupy the remaining space of the epithelium. They vary in size and shape. Some of them are columnar and others are

cubical. A minute observation of the nuclei of these cells reveals the fact that they are in different stages of division. Two types of nuclei can be made out. One of the types takes heavier stain and these are generally nuclei of the daughter cells ; while the other type takes a lighter stain and are generally nuclei of bigger cells which are in an active state of division. The cells by dividing increase the thickness of the epithelium as well as the surface ; hence the folded nature of the epithelium.

Sub-epithelial connective tiasue.—This region of the pharyngeal wall is very like that of the anterior region of the pharynx in containing a compactly arranged connective tissue next to the epithelium and a loose areolar connective tissue beneath it. The latter contains in its meshes longitudinal muscle bundles. Some fat cells could be made out here and there in this region. Both the regions are well vascularised and innervated.

Muscularis.—The muscle bundles form two coats in this region. The longitudinal muscle bundles which are found in the areolar connective tissue forms the inner coat of musculature. The transversely disposed muscle bundles occupy fairly a quarter of the thickness of the pharyngeal wall and form the outermost coat. The muscle bundles are of the striated type.

(*c*) *The structure of the pharyngeal dental region.*—The epithelium in this region is very much like that of the preceding region but for the fact that it is not much folded. The mucous cells are not found in abundance. At the base of the areolar connective tissue there seems to be a bundle of muscle fibres arranged obliquely for the movement of the pharyngeal teeth. The latter are elevated from the general level and look like convex discs. The arrangement of muscle bundles is such that the set or sets act as a whole.

The development of the secondary pharyngeal tooth-germs.—The development of secondary tooth-germs is very interesting to study. The epithelium of this region sinks down in the sub-epithelial connective tissue to form solid cords, thus making the base of the epithelium look like a festoon. The cells at the tip of the cords cut out a knob of cells which arrange themselves to form hollow spheres. For some time they retain the connection with the epithelium and later on they sink into the connective tissue which finally surrounds them in this region. In sections they appear circular. The wall of the hollow sphere consists of two tiers of cells concentrically arranged. They are cubical or columnar and the latter seem mostly to be derived from the former, by division. Later the inner tier of cells gives rise to others which fill in the hollow space, to form the central cells. At this time the sphere is solid. A little later some transparent structureless substance is formed between the central cells and the inner layer of the sphere. This forms the substance

of the tooth. The sphere elongates towards the pharyngeal lumen and as it does so, the tooth substance becomes conical and later becomes elongated. The tip pierces its investing layer of cells and projects a short distance in the pharyngeal cavity. Meanwhile the base becomes slightly swollen out before it spreads out in the sub-epithelial connective tissue tangentially to form a firm support ; it constricts again to form a narrow neck. The central core of cells remains for some time unaltered and ultimately disappears. The worn out teeth are replaced by freshly formed secondary ones (Plate XI).

4. *Œsophagus.*

The œsophageal wall consists of a stratified epithelium, sub-epithelial connective tissue, muscularis and serosa.

Epithelium.—The epithelium is composed of mucous cells and undifferentiated cells. Taste buds are of very rare occurrence. The epithelium differs in its structure as it passes from the anterior to the posterior region. The epithelium of the anterior region is thicker than that of the posterior part. The folds of the anterior portion which are longitudinal and uninterrupted are blunt towards their tip and are of uniform size. The crypts are narrow. In the posterior region the epithelium is also thrown into folds, and bear sharp free edges which meeting together almost obliterate the lumen of the œsophagus. These folds branch mostly towards one side.

The mucous cells of the anterior region resemble to a great extent those of the pharynx and are found at the sides and bottom of the crypts. Most of the cells are greatly elongated and contain a basal nucleus which is either flattened or tapers into a point. A big mucous cell measures 47 microns along its long axis and 18 microns along its short axis. The cell cytoplasm is reticular in appearance. These cells mark the transition between the pharynx and œsophagus proper (Plate XII).

In the posterior region the epithelium consists of a greater number of mucous cells than in any other region. They are of very big size and look like sacs containing mucus in them. These cells are mostly distributed in one or two layers. A majority of them open into the œsophageal cavity. The mucous cells have nuclei with distinct nucleoli (Plate XIII).

The actively dividing undifferentiated cells are found towards the anterior part of the œsophagus. Different stages of dividing nuclei could be made out. Some of the nuclei are big and take up a light stain while others are small and take up a heavy stain. Few cells contain chromatin material without a distinct nuclear membrane. Some of the big cells are just like those found in the buccal epithelium. A few of the undifferentiated cells form a group and their cell outlines cannot be made out but chromatin

granules could be discerned in groups. They seem to contain some greenish yellow bodies.

In the thickness of the epithelium a few nuclei could be seen which are not well stained and they have no nuclear membrane. Some of the nuclei do not possess nucleoli.

Taste buds are of rare occurrence. A few structures simulating these bodies are found sunk below the surface of the epithelium communicating with the œsophageal cavity by a narrow passage leading from the gustatory pore.

Sub-epithelial connective tissue.—This region consists of connective tissue fibres loosely arranged so as to form a mesh-work. It is well vascularised and innervated. Some nuclei are found here and there. This tissue not only forms a central core for the folds but also forms a layer all round the epithelium. In the posterior region, the connective tissue fibres are so closely set that it does not appear like a mesh-work, but it looks like a connective tissue sheet studded with nuclei.

Muscularis.—The musculature can be divided into an inner longitudinal layer and an outer circular coat. The cut ends of longitudinal muscle bundles are found in the meshes of the sub-epithelial connective tissue. They gradually decrease in number posteriorly. The circular muscle fibres are transversely disposed and occupy a major part of the thickness of the wall of the œsophagus. The muscle fibres are of the striated variety.

Serosa.—The serosa is a conspicuous layer consisting of connective tissue fibres and cells, blood vessels and nerves, covered externally by flattened peritoneal cells. This coat of the œsophagus is external to circular muscle fibres and is continuous with the connective tissue found in this region.

The pneumatic duct joins the posterior part of the œsophagus. It is internally lined by a single layer of columnar epithelial cells. The circular muscle fibres of this duct are continuous with the circular muscle fibres of the œsophagus.

It will be of interest to consider the structure of the œsophagus just before it joins the stomach. The epithelium is gradually transformed from the mucous type to the single layered columnar epithelium of the stomach. This transformation is seen at the tips and sides of the œsophageal folds. The basal nuclei of the mucous cells are converted into the nuclei of the columnar cells. Some of these columnar cells are engaged in secretion. In this region the extraordinarily reduced longitudinal muscle bundles are a feature of interest to be noted (Plate XIV).

5. *Stomach.*

This part of the digestive tract can be structurally divided into an anterior cardiac portion and a posterior pyloric region.

Cardiac region of the stomach.—The cardiac stomach wall is composed of gastric epithelium, tunica propria, glands, connective tissue layer, muscularis and serosa (Plate XV).

Epithelium.—The epithelium is thrown into a number of gastric folds. Each fold is supported by connective tissue fibres. The cells forming the epithelium are roughly columnar and vary in shape according to their position as well as at different stages of digestion.

The cells covering the tips of the gastric folds can be correctly described as trumpet-shaped, when they are not actively engaged in secretion. These are elongated cells whose free surfaces are wide while their bases are produced into filaments which join the tunica propria. The cell cytoplasm is finely granular and possesses a big ellipsoidal or spherical nucleus which is found either in the centre or the distal third of the cell. The nucleus contains a deeply staining nucleolus and some chromatin granules (Plate XVI).

The cells described above present a different picture altogether when they are actively engaged in secretion. The first stage of activity is manifested by the appearance ot a transparent, tiny globule of fluid secreted by the cell at the free surface. This gives a characteristic appearance to the epithelium, since the distal parts of these cells take a lighter stain. The second stage of activity is marked by the growth of the secreted product till it assumes a spherical shape. At this stage the cell at its distal end presents the appearance of a cup. Subsequently, the secreted product is expelled into the gastric lumen. Probably, these cells are engaged in secreting a fluid which acts on the food-stuffs.

The cells lining the crypts may be appropriately described as columnar. The nucleus is situated generally in the basal third of the cell and exhibits the same characters as mentioned above. In an inactive condition, the cell cytoplasm is finely granular and while they are active, the distal third of the cell stains very lightly and at the free surface the secreted product accumulates.

The cells found at the bottom of the crypts are roughly cubical or rectangular and their bases are slightly wider than their distal surfaces. Their nuclei are more centrally placed. The cells of this region are also, to a certain extent, concerned in the secretory activity.

The formation of simple, tubular glands from the gastric epithelium will be described in the section dealing with glands.

Tunica propria.—The tunica propria is a term applied for that part of the connective tissue found between the gastric epithelium and glands. In fact, it is a part of the sub-epithelial connective tissue which has been isolated from the rest by the peculiar way by which the glands are derived from the gastric epithelium. This region consists of connective tissue fibres and in their meshes are found a good number of capillaries. There are many nuclei with a variety of shapes seen in this region, of which the oval or elongate type is common.

Glandular region.—This region is divided into compartments or blocks by the connective tissue septa found at regular intervals which connect the tunica propria on the one hand and the connective tissue found beneath the glands on the other hand. Elsewhere the two are separated by the glands.

The gland cells are usually arranged in such a manner that they generally form simple tubes placed at right angles to the surface, separated from one another by connective tissue septa. This simple arrangement is disturbed in some places by branching. Some of these glands open at the bottom of the crypts. A tangential section reveals the cut-ends of the glands which are either circular or oval in outline and are formed from four to six cells, sometimes with a lumen in the centre and at times without it. Each tube is isolated from the adjacent ones by septa which consist of connective tissue fibres and blood capillaries. Some connective tissue cells of a triangular type could be seen with fibres proceeding from three corners with a central nucleus.

The cells composing the glands can be classified into groups according to their position and structure.

The cells towards the epithelium are roughly cubical in shape and the cell outlines are distinct. The surface of the cells towards the gland lumen is smaller than that of the opposite side. The nucleus is of the spherical type and takes a heavy stain with a well-stained nucleolus containing some chromatin granules. The cytoplasm exhibits a fine reticular appearance.

The cells forming the basal region of the glands exhibit the same structure as above except for the cytoplasm which is coarsely granular, and the granules are quite conspicuous by their number and size. These granules are zymogen granules, since they are concerned with the production of the enzymes.

It is very interesting to study as to how the glands are formed by the epithelium. Some of the sections when examined present the following structure :—

Just beneath the epithelium under a particular focus a curved row of nuclei is seen which gives the appearance of a hollow invagination of the epithelium being formed. If the focus is changed so that the underlying layers of the sections might be viewed, a tangential view of the cells which presents a honey comb appearance can be seen. From this it is inferred that a hollow invagination of the epithelium is taking place. The cells at the bottom and the sides of the pits so formed differ in structure from the cells of the epithelium. When this sinking is taking place, it is covered automatically by a coat of connective tissue. The invagination proceeds deeper down and the lumen narrows. The cells at the bottom of the tube become highly granular. Thus the glands and their connective tissue covering are derived from the modification of the epithelial cells, and the sub-epithelial connective tissue respectively.

Connective tissue region.—This region not only forms the central core of the stomach folds but also forms a circular layer internal to circular muscle fibres. The correct idea of this statement could be grasped by considering the nature of the stomach folds. These folds are distinct from the epithelial folds. If the aggregate of the epithelium, tunica propria and the glandular regions is considered as forming a compound layer, the stomach folds are formed from the folding of this compound layer and the connective tissue forms the central core of these folds. A large number of nuclei could be made out in this region and the majority of these nuclei are ovate or elongate in shape, take a heavy stain and consist of chromatin granules. The cut ends of a few longitudinal muscle bundles are visible: probably these are the remnants of the longitudinal muscle bundles of the œsophagus. This is not characteristic of the stomach and is found only in the transitional region (Plate XV).

Muscularis.—The musculature consists of a thick internal circular muscle coat and a thin external longitudinal muscle layer. The muscle fibres of the stomach are of the non-striated type except at the region where the œsophagus passes into the stomach.

Serosa.—The serosa is of considerable thickness in this region and its structure is very like that of the œsophagus. At different regions of the stomach wall, the serosa is directly connected with the connective tissue layer by connective tissue fibres.

Pyloric region of the stomach.—This part of the stomach presents a strikingly different appearance from that of the cardiac region. The stomach wall is not thrown into folds but the gastric epithelium presents the feature of folds and crypts. The structure of the columnar cells of the

epithelium is very like that of the cardiac part of the stomach. The absence of the glandular region is conspicuous. The sub-epithelial connective tissue is very like that of the œsophagus. In the posterior region the circular muscle fibres increase in thickness to form the sphincter which projects into the lumen of the anterior part of the intestine for a short distance. The longitudinal muscle fibres and serosa are similar to those of the cardiac part of the stomach (Plate XVII).

6. *Intestine.*

The intestinal wall is composed of a columnar epithelium, sub-epithelial connective tissue, muscularis and serosa (Plate XII).

Epithelium.—It is characterised by the presence of columnar cells and is thrown into a number of folds which occasionally branch. In addition to this there are certain mucus producing cells of the goblet type which are modified columnar cells. There is still another type of cell, the wandering cell or the leucocyte.

The cytoplasm of the columnar cells is finely granular in appearance. The nucleus occupies the basal third of the cell and takes a moderately good stain and contains many chromatin granules besides a well-stained nucleolus. Towards the free surface of the cells a vertically striated plate-like structure could be made out, the top plate. The columnar cells at the tips of the folds, especially at the anterior region of the intestine, presents a different picture when they are actively engaged in absorption. They increase in size and their cytoplasm exhibits a coarsely granular appearance. The nucleus takes a lighter stain. In this active region the top plate cannot be made out. Though the columnar epithelium is one cell layer in thickness, yet it shows three to four rows of nuclei in a section which is 6 microns in thickness.

The goblet type of cells are of rare occurrence and they are of two types ; they differ in staining reactions. Thus one type of cell does not take stain. Both the types are derived from the modified columnar epithelial cells. Such of those that open to the exterior are found near the surface, while others are found deeper down. The cells of the other type, though they resemble the above-mentioned one with respect to their distribution, yet differ in their staining reactions. These cells which take a heavy stain are studded with coarse granules. Some cells of this type appear like tubes with their nuclei basally situated. The free surface is at a higher level than the top plate and the edge flanks all round, thus furnishing the appearance of a trumpet. These cells are of very rare occurrence. As to how these cells differ in function from the above-mentioned type is not certain (Plate XIX).

The wandering cells or the leucocytes do not belong to the epithelium proper. They are immigrants and hence they are found in the interstitial spaces at the basal part of the epithelium. The cell outline is roughly spherical and the cytoplasmic area is transparent containing a very heavily staining nucleus: near the base of the epithelium, these cells are found in greater number than near the periphery. By the similarity of the structure of cells found both at the base and at the peripheral regions, it could be inferred that the cells wander from the basal to the peripheral regions.

Sub-epithelial connective tissue.—This tissue not only forms the central core of the folds but also forms a thin layer internal to circular muscle fibres. This is richly vascularised and innervated. Very often in sections a clear space appears in this tissue near the tip of the folds, probably these spaces function as the lacteals of mammals. Oval or elongate nuclei with chromatin granules can be discerned in this region. In the meshes of the connective tissue near the base of each fold a big blood vessel with its external muscle coat and an internal endothecium can be made out.

Muscularis.—The muscle fibres are of the smooth non-striated type. These are arranged to form an internal circular layer and an external longitudinal layer which is a comparatively thinner layer than the former. The circular muscle layer varies in thickness in one and the same section at different regions.

Serosa.—This layer is thickest in this region of the alimentary tract and in its composition it is very like that found covering the stomach. In some sections, the sub-epithelial connective tissue penetrates the musculature and establishes its connection with the serosa, since it is from this layer it receives its vascular supply.

The bile and the pancreatic ducts join the anterior part of the intestine, near the pyloric region of the stomach, at one and the same place. These ducts open in a strange manner. They enter as such through the muscularis and like one of the folds reach the central lumen where it opens. The tube is internally lined by columnar epithelial cells with connective sheaths surrounding them.

Conclusion.

The most striking histological features of the digestive tract of *Saccobranchus fossilis* are the following:—

1. Taste buds roughly resembling those of the mammals in structure are present in the lips, buccal epithelium and pharynx in great numbers and a few are present in the œsophageal region.

2. In the buccal epithelium and in the anterior part of the pharynx there are giant cells, conspicuous by their one or more nuclei. These cells are dividing cells and no mention is made of them by any of the previous authors.
3. The anterior region of the pharynx is separated from the posterior part, for reasons mentioned in the paper.
4. No part of the free surface of the posterior region of the œsophagus, is free from mucous cells. External longitudinal muscle bundles are absent in the œsophagus.
5. The pneumatic duct comes and joins the posterior part of the œsophagus, while the bile and the pancreatic ducts open into the anterior part of the intestine just near the pyloric end of the stomach.
6. The stomach is divisible into cardiac and pyloric regions. The former is conspicuous by the presence of the glands while the latter is devoid of them.
7. There is no pyloric valve, nevertheless, the same object is achieved by the presence of the pyloric sphincter. There is no intestino-rectal valve.

Histology of the Digestive Tract of Macrones vittatus.

Macrones vittatus and *Saccobranchus fossilis* resemble each other to a great extent regarding histological details of their digestive tracts, since both of them are allied species. To avoid unnecessary repetitions, only those regions of the alimentary canal which exhibit structural differences are dealt with.

General Morphological notes.—The alimentary tract of *Macrones vittatus* is not a uniform tube throughout and the intestine is not greatly coiled. The short nature of the intestine indicates the fact that it must be carnivorous. As in *Saccobranchus*, the digestive tract may be externally differentiated into different regions. The pneumatic duct opens into the posterior region of the œsophagus.

Lips.—The epithelium of the lip is strikingly different from that of *Saccobranchus*, and comprises of undifferentiated and mucous cells. The cell outlines of the undifferentiated cells cannot be made out. The nuclei of these cells situated towards the free surface of the epithelium are spherical in shape each with a single nucleolus. The nuclei of the remaining undifferentiated cells are elongated in a radial direction ; they take a heavy stain and each one of them contains a single nucleolus with some chromatin granules. The undifferentiated cells towards the base of the epithelium

are columnar in shape. The mucous cells are situated peripherally and are of the spherical type, with a basal nucleus.

Taste buds are few in number ; they are unlike those found in *Saccobranchus*. Pigment bodies are of rare occurrence (Plate XX).

Buccal cavity.—The epithelium of this region can be differentiated from the same region of *Saccobranchus* by the rare occurrence of the taste buds. The superficially situated mucous cells are spherical in shape. The cell outlines of the undifferentiated cells cannot be made out ; their nuclei are spherical and take a heavy stain. A few giant cells are found. The presence of a thick layer of stratum compactum beneath the epithelium is another important feature of this region (Plate XXI).

Pharynx.—The anterior pharynx is characterised by the presence of a distinct stratum compactum and by the absence of musculature. The stratified epithelium of this region is strikingly different from that of the same region of *Saccobranchus*. The epithelium consists of undifferentiated cells and conspicuous cells. The undifferentiated cells are of various sizes and shapes and are found in different stages of division. Their nuclei take a very heavy stain ; the cytoplasm of the cells is finely granular. The conspicuous (giant) cells are superficially situated, covered by a single layer of cells towards the free surface. Their nuclei can be seen in different stages of division. Mucous cells are of very rare occurrence. The stratum compactum is present in the form of a thick, clear, wavy, uniformly staining band of fibres.

The posterior pharyngeal region is marked by a distinct muscularis which is complicated by the addition of oblique muscle bundles. The stratum compactum is absent. The epithelium of this region is about seven to eight cells thick and has mucous cells, undifferentiated cells, conspicuous cells and taste buds (Plate XXII).

The mucous cells are superficially situated and most of them open to the pharyngeal cavity. They are of spherical shape, and their cytoplasm exhibits a reticular structure. Each mucous cell has a flattened basal nucleus.

The undifferentiated cells are disposed in layers. The cells of the middle layers are roughly cubical, while the cells of the basal layers are columnar and are actively dividing. The nuclei are well stained and are found in various divisional stages.

The conspicuous cells are very like those described for the preceding region. From the similarity of shape between these cells and that of mucous cells, it may be inferred that they are in the process of being converted into mucous cells.

A few taste buds are present and are unlike those found in *Saccobranchus*. They are situated deeper down in the thickness of the epithelium on slightly raised areas of the sub-epithelial connective tissue and are of spherical type. In a majority of cases, they are covered over by cells of the superficial layer of the epithelium, while in a few cases they communicate with the pharyngeal cavity by a gustatory pore.

The rest of the digestive tract of *Macrones* does not show any striking structural differences which call for comment.

BIBLIOGRAPHY.

Dawes, B., "The histology of the alimentary tract of the Plaice, *Pleuronectes platessa*," *Quar. Jour. Micr. Sci.*, 1929–30, **73**. Pt. 11, 243–74.

Greene, C. W., "Anatomy and histology of the digestive tract of the King Salmon," *Bull. U. S. Bur. Fisheries*, 1912, **32**, 73–100.

Mary, Dora Rogick, "Studies on the comparative histology of the digestive tube of certain Teleost fishes, Minnow (*Campostoma anomalum*)," *Jour. of Morph.*, 1931, **52**, No. 1, 7–25.

Irving, H. Blake, "Studies on the comparative histology of the digestive tube of certain Teleost fishes. The sea bass (*Centropristes striatus*)," *Jour. of Morph. and Physiology*, 1930, **50**, No. 1, 39–70.

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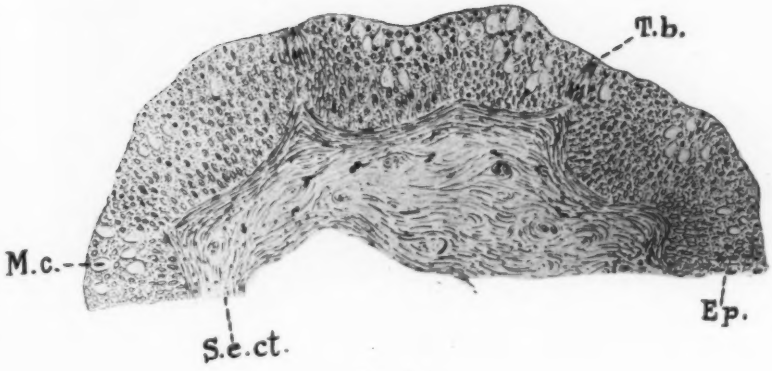
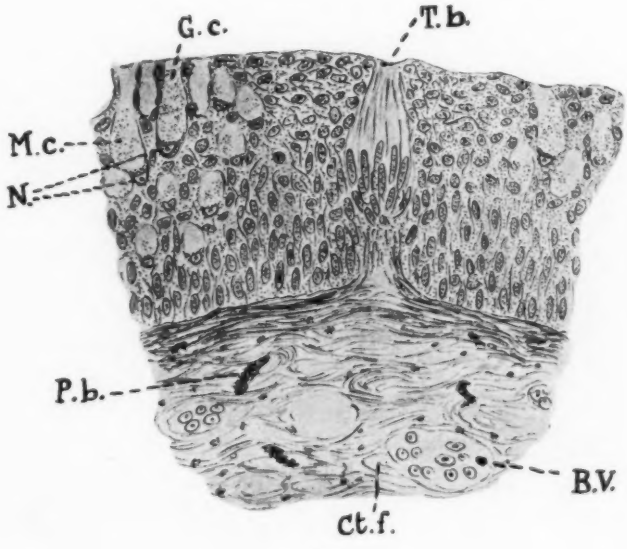


FIG. 1 A.



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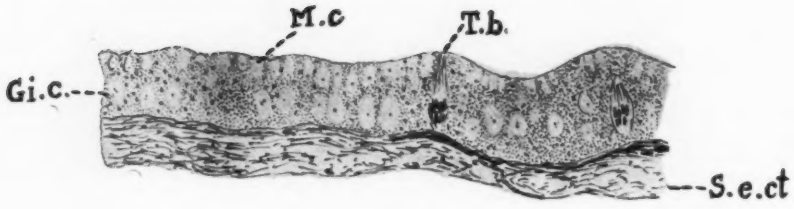

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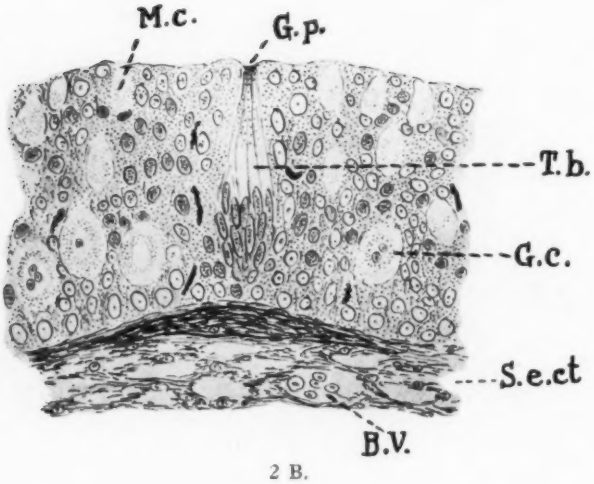

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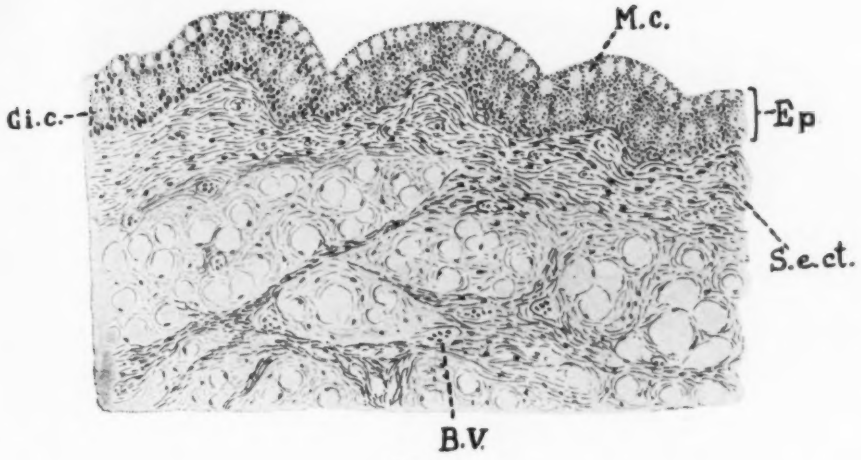

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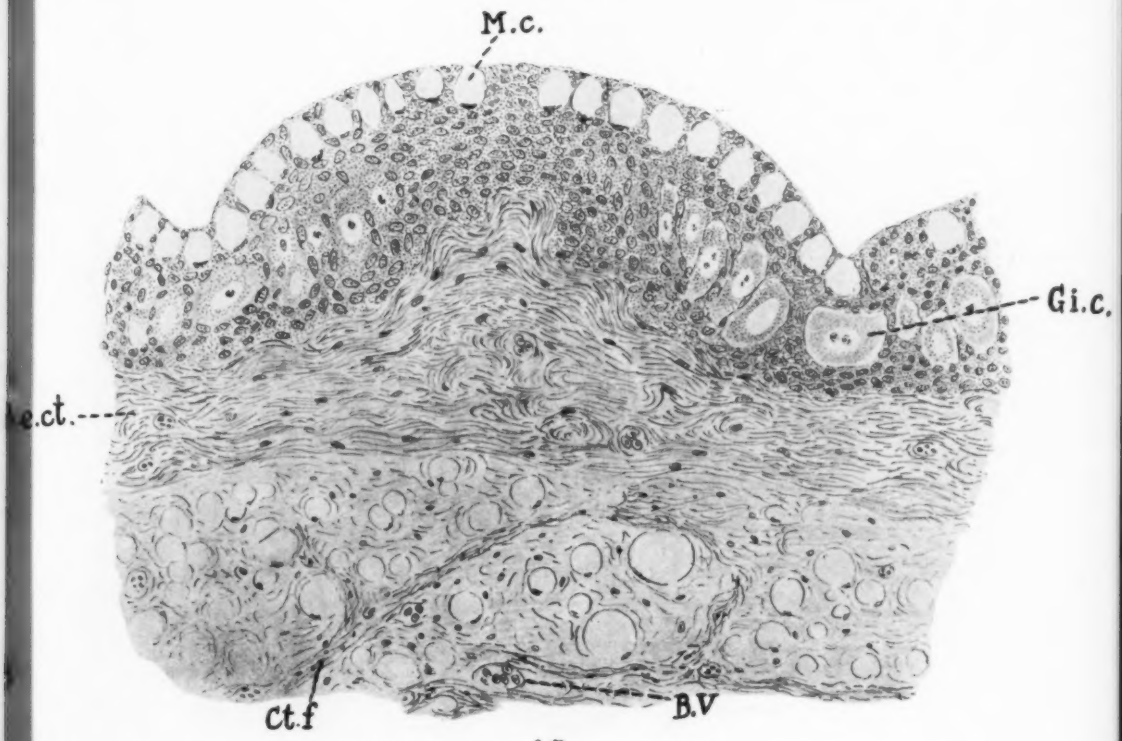

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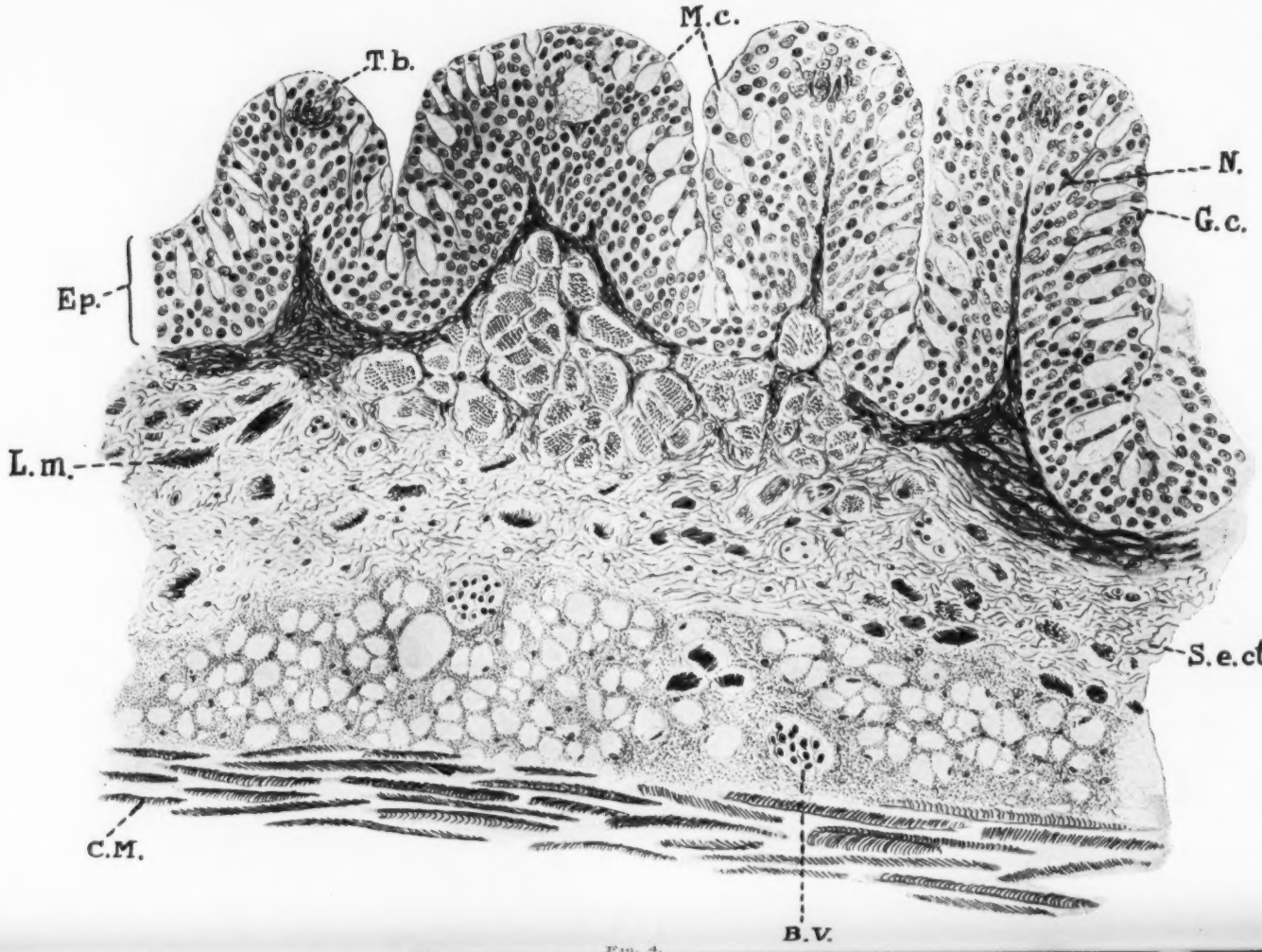

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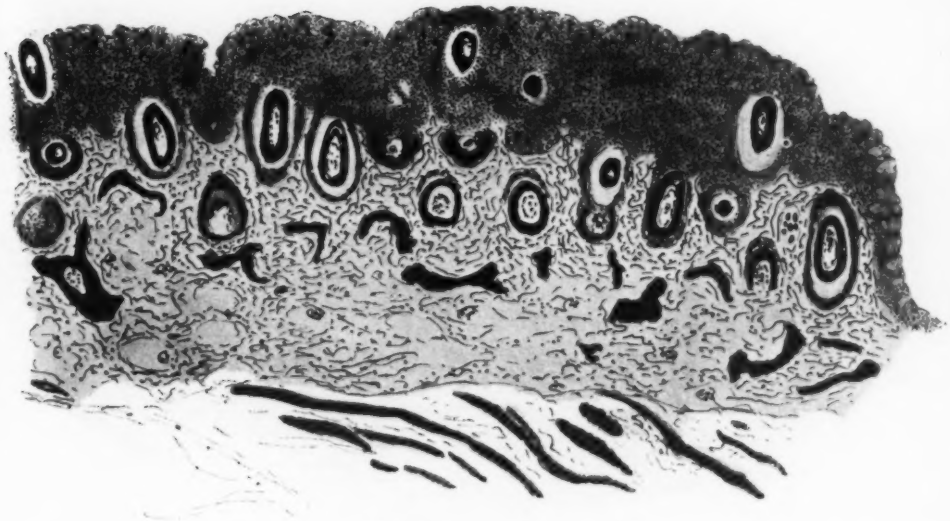

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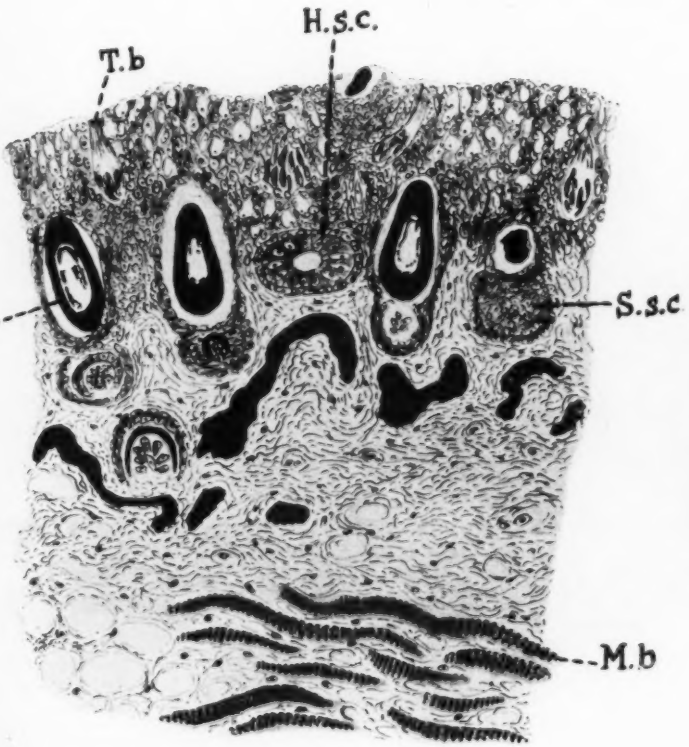

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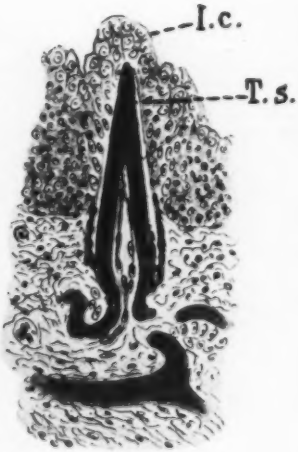

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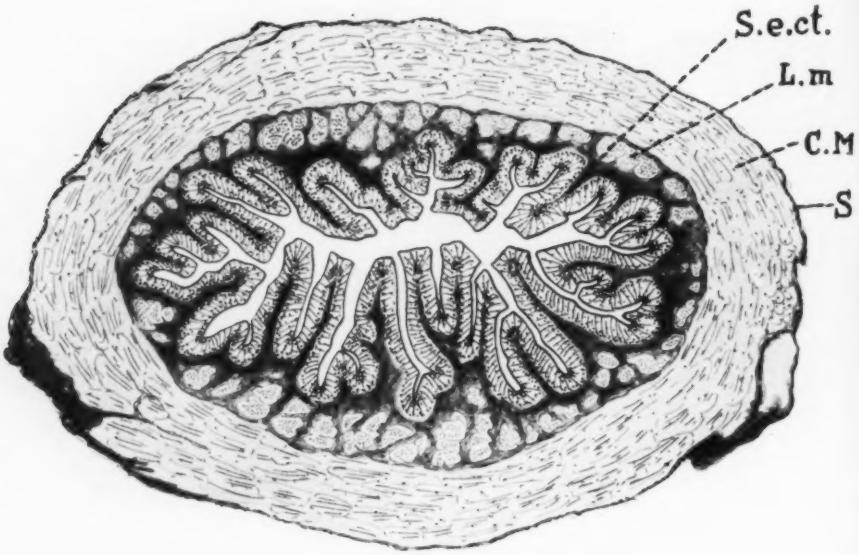

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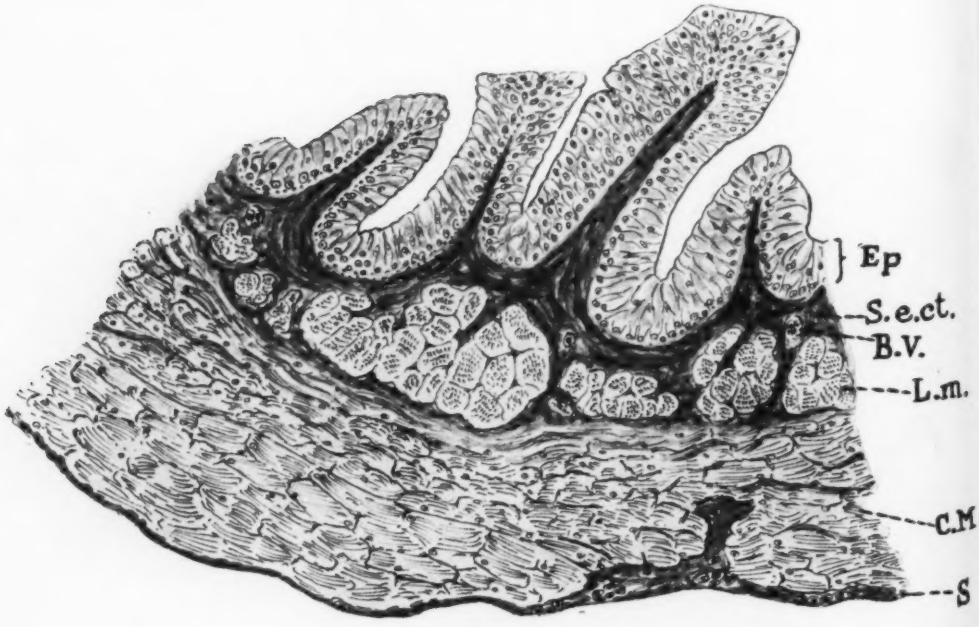

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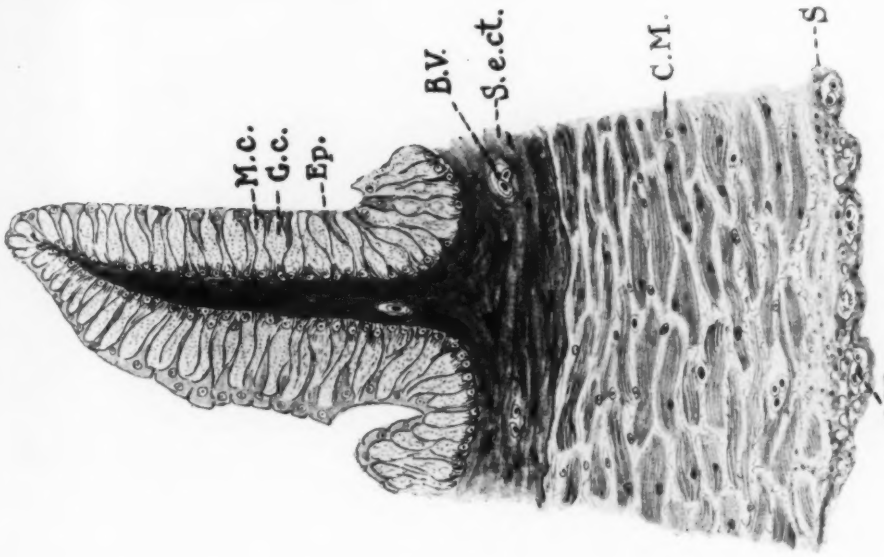

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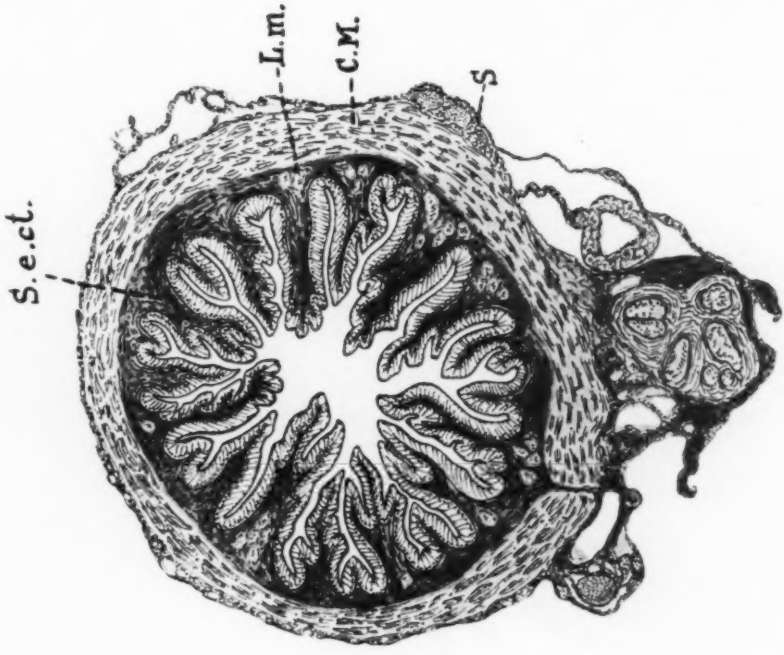

Fig. 7 A.

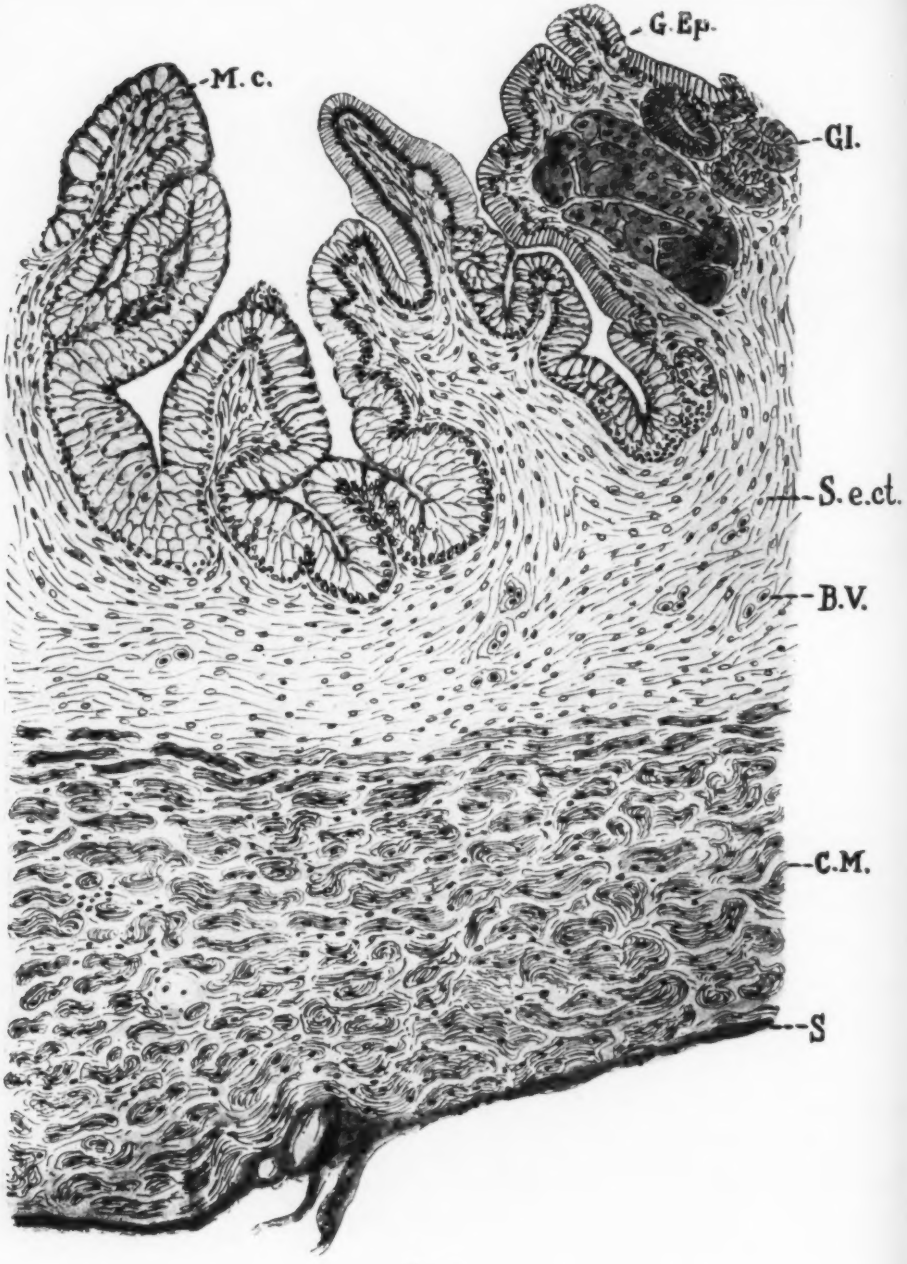

Fig. 8.

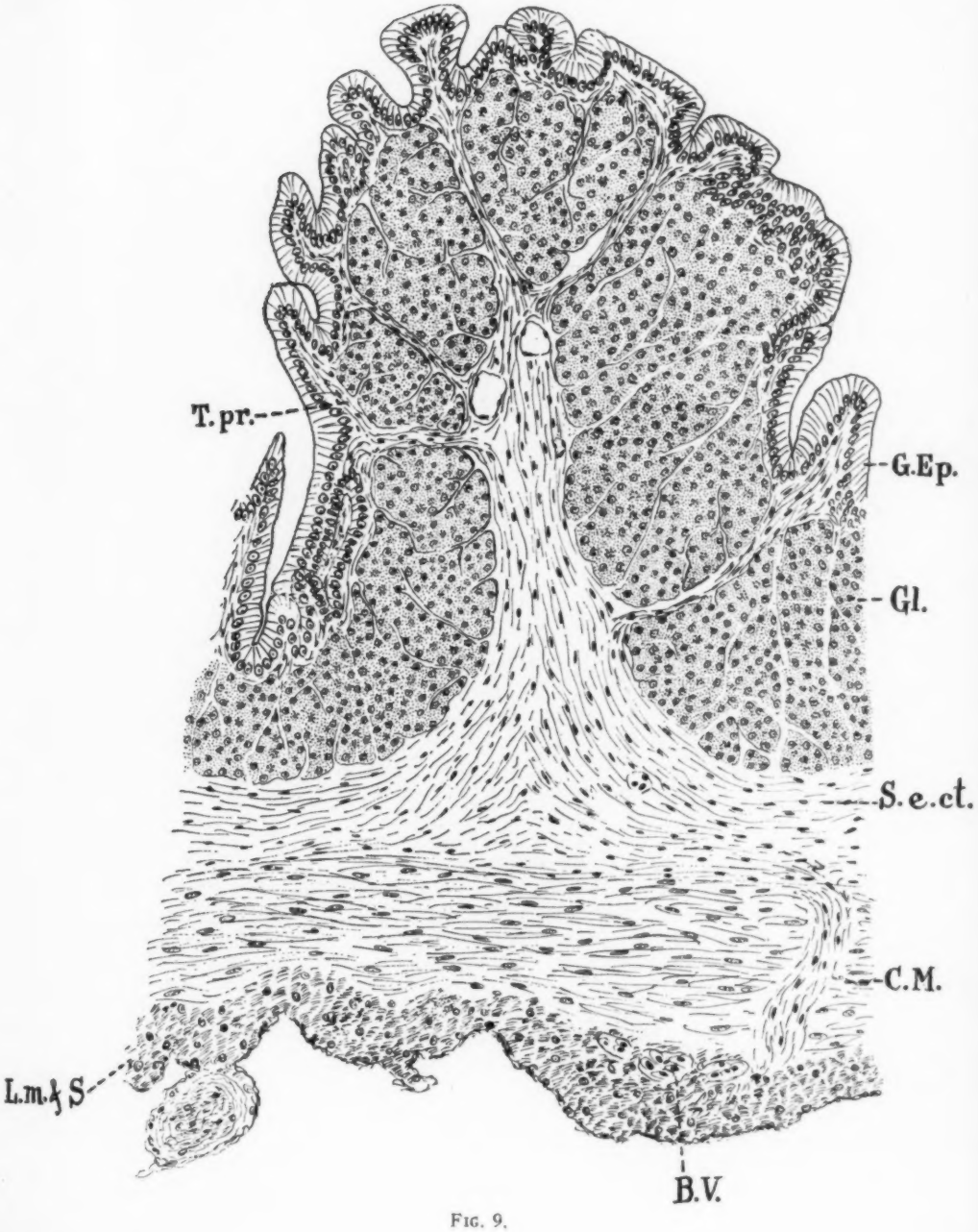

FIG. 9.

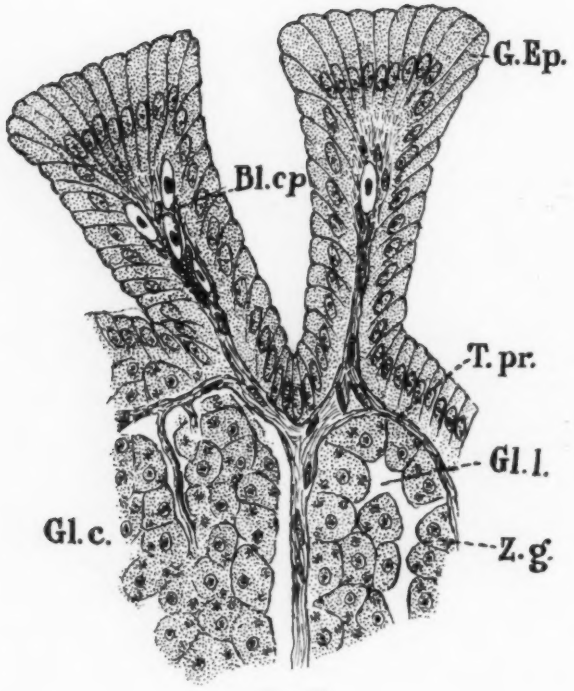

FIG. 10.

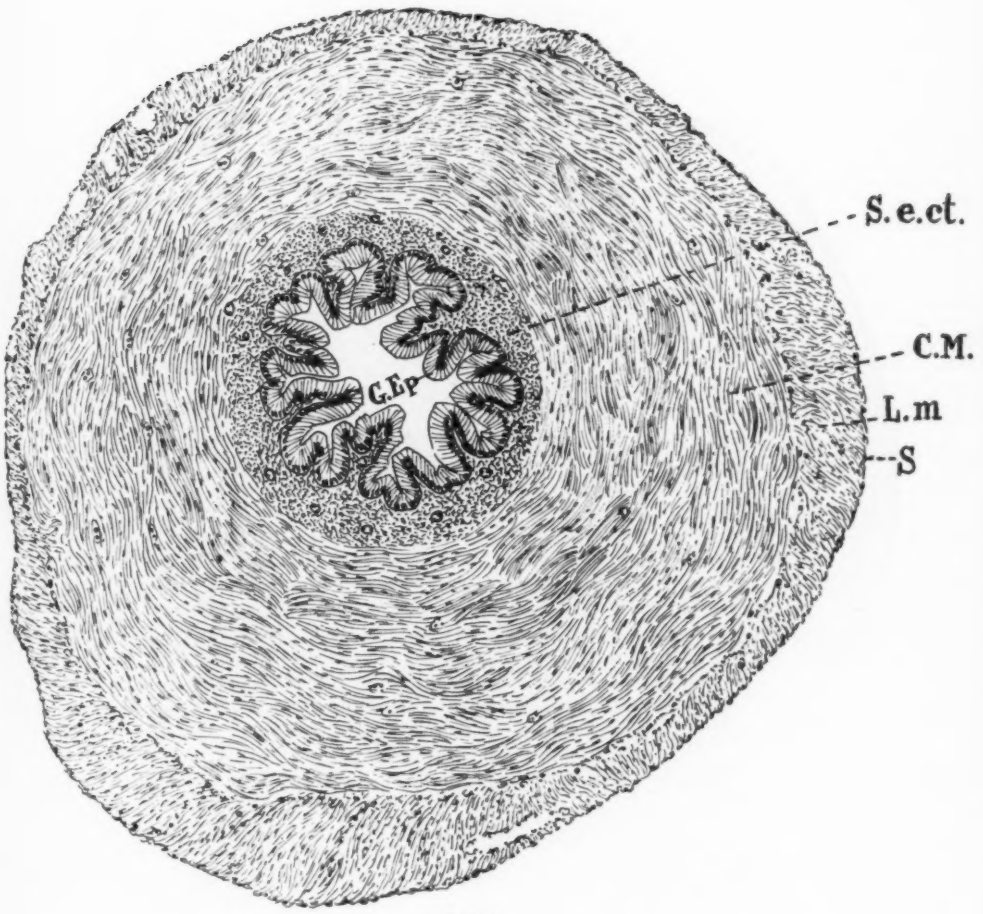

FIG. 11.

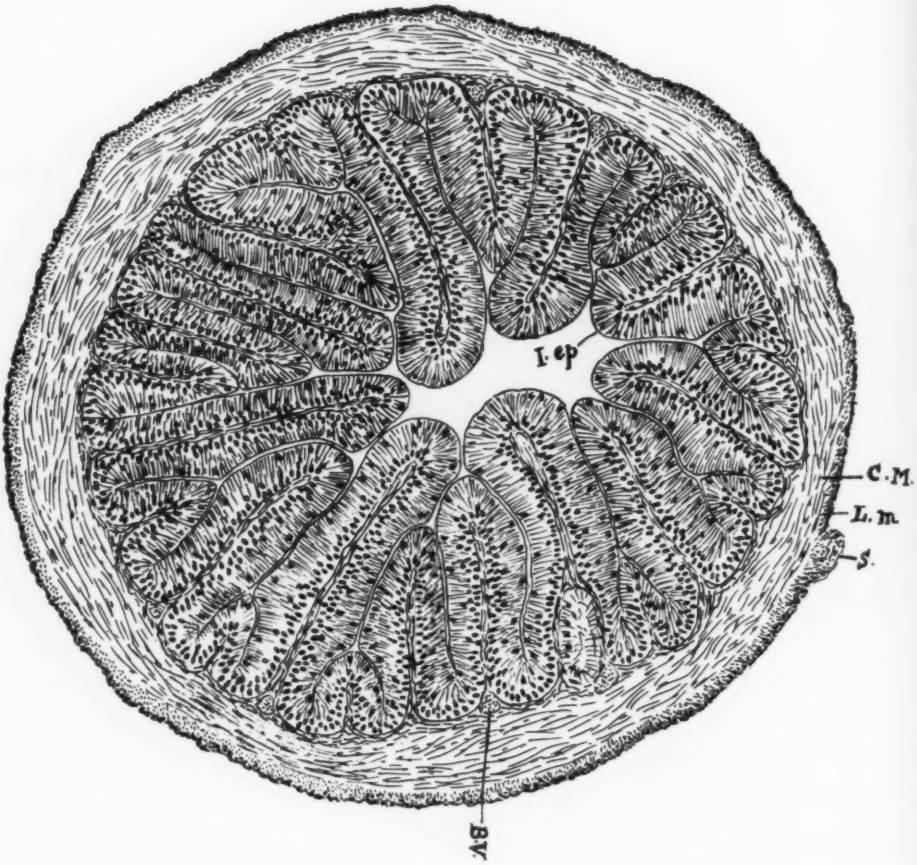

FIG. 12.

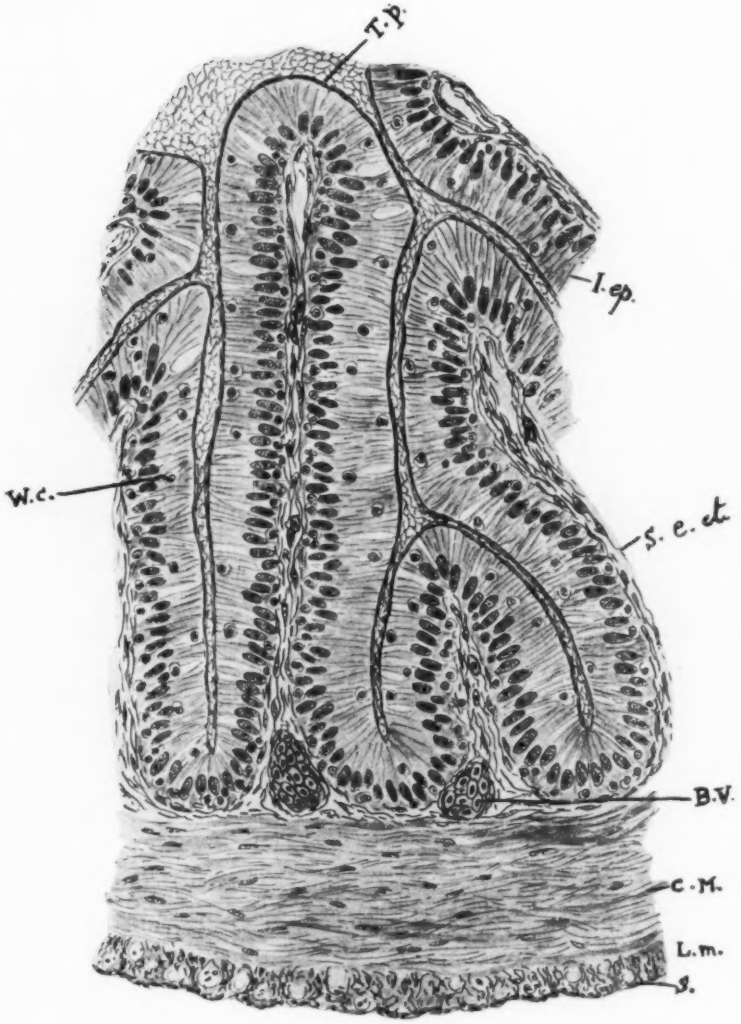

FIG. 13.

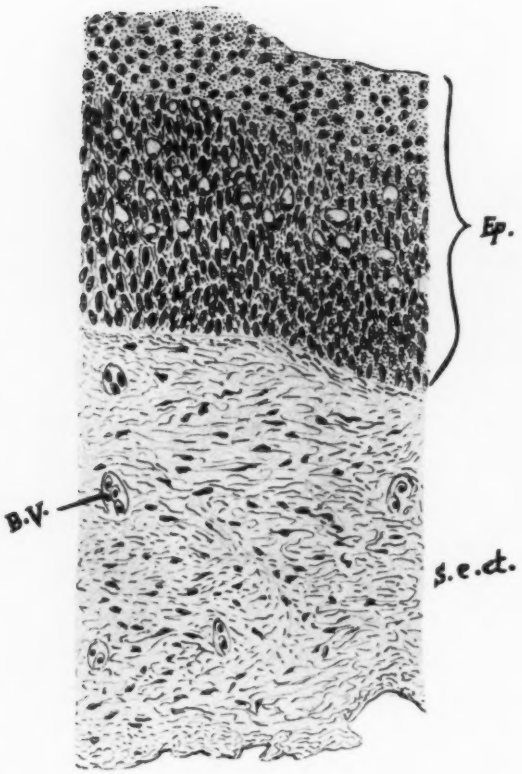

FIG. 14.

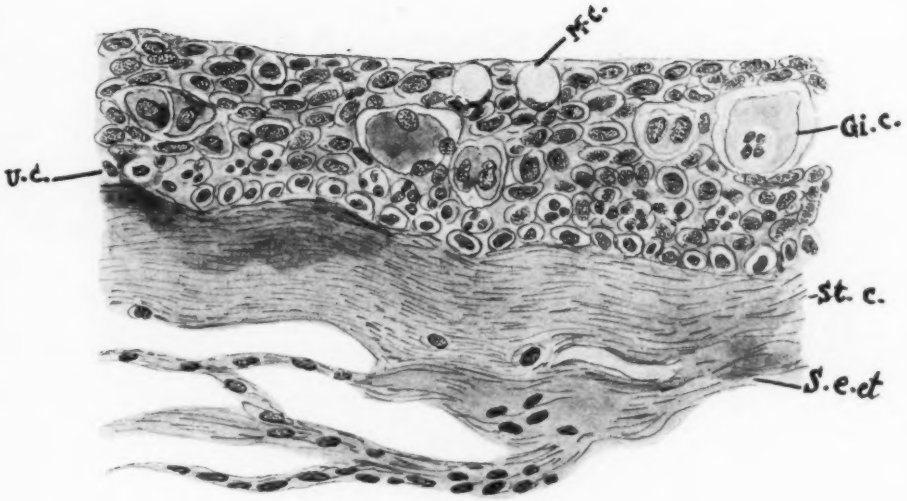

FIG. 15.

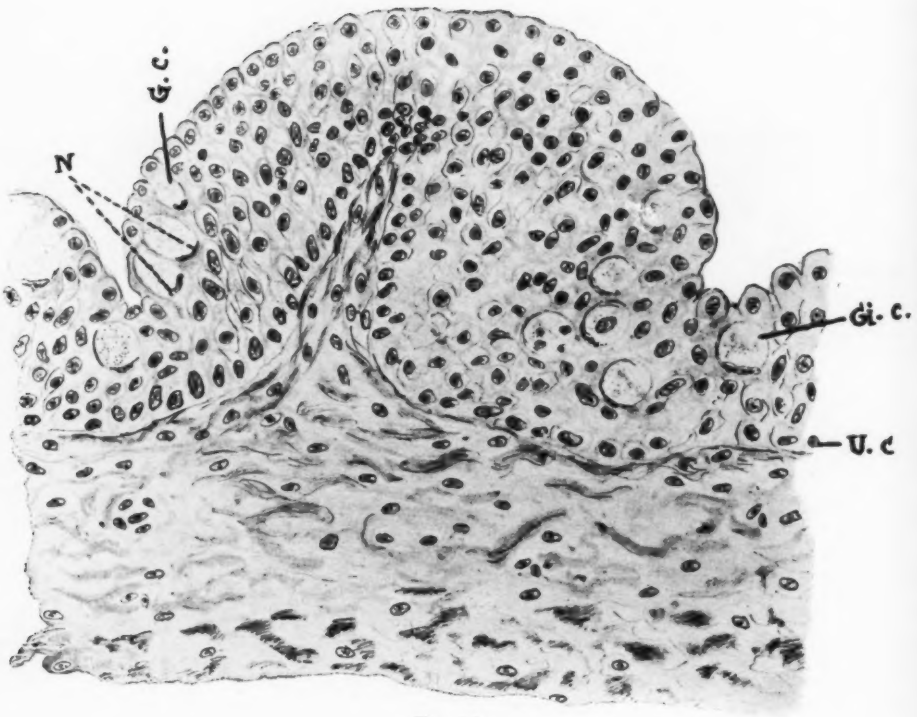

FIG. 16.

PLATE XIV.

FIG. 8. Section showing the transition between the œsophagus and stomach, highly magnified.

PLATE XV.

FIG. 9. Cross-section of a part of the wall of the stomach.

PLATE XVI.

FIG. 10. Two villi of the stomach with the gland cells highly magnified.

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PLATE XVIII.

FIG. 12. Cross-section of the intestine.

PLATE XIX.

FIG. 13. Few of the villi of the intestine highly magnified

(*Macrones vittatus*).

PLATE XX.

FIG. 14. Cross-section of the lip.

PLATE XXI.

FIG. 15. Cross-section of the buccal epithelium.

PLATE XXII.

FIG. 16. A part of the cross-section of the wall of the pharynx.

KEY TO LETTERING.

B. V.—Blood vessel.
Bl. cp.—Blood capillaries.
C. M.—Circular muscle.
Ct. f.—Connective tissue fibres.
Ep.—Epithelium.
G. c.—Goblet cell.
G. Ep.—Gastric epithelium.
G. p.—Gustatory pore.
Gi. c.—Giant cells.
Gl. l.—Gland lumen.
Gl. c.—Gland cells.
Gl.—Gland.
H. s. c.—Hollow sphere of cells.
I. c.—Investing cells.
I. ep.—Intestinal epithelium.
L. m.—Longitudinal muscle.
M. c.—Mucous cells.
M. b.—Muscle bundles.
N.—Nucleus.
P. b.—Pigment bodies.
S.—Serosa.
S. s. c.—Solid sphere of cells.
S. e. ct.—Sub-epithelial connective tissue
St. c.—Stratum compactum.
T. b.—Taste bud.
T. p.—Top plate.
T. pr.—Tunica propria.
T. s.—Tooth substance.
U. c.—Undifferentiated cells.
W. c.—Wandering cells.
Z. g.—Zymogen granules.

STUDIES ON THE STRUCTURE OF THE GOLGI APPARATUS.*

II. Liver Cells of *Rhacophorus maculatus* Gray.

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(*Research Fellow, Department of Zoology, University of Madras.*)

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(Communicated by Prof. R. Gopala Aiyar.)

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Introduction.

In two previous papers the author in collaboration with Professor R. Gopala Aiyar (1936 *b* and 1937) gave some tentative suggestions regarding the probable mode of evolution of the network-like Golgi apparatus of vertebrate somatic cells from the discrete Golgi bodies of invertebrates. There we briefly discussed the position of the idiosome in the dictyosome of invertebrates and in the network of vertebrates. It was suggested that tubular networks with a chromophobic core may be present or that networks like granules may be able to differentiate a chromophobic region. Further studies have confirmed the above hypothesis and evidence will be presented in this paper to show that our suggestions are actually proved in the liver cells of *Rhacophorus*. That the chromophobic region has nothing to do with the sphere substance or "archoplasm," could be made out from Part I of

* This Thesis along with Part III of these "Studies" was awarded the Maharaja of Travancore Curzon Prize by the Madras University in August 1937.

these Studies (Subramaniam and Ganapati, 1938) where it has been shown in *Lecudina*—a gregarine—that while the Golgi bodies show a duplex structure, the centriole is intranuclear.

Historical.

The idea that the Golgi apparatus may have a duplex structure has been present in the minds of all students of the Golgi apparatus. Cajal (1914) who tried to harmonize the ideas of Holmgren and Golgi suggested that the material blackened by silver methods was contained in canal-like passages. Leaving alone the details of the analysis, Cajal's work suggests the idea of a lipoidal material enclosed in a limiting membrane. Hirschler (1918), from a long series of investigations, came to the conclusion that when the Golgi bodies are spherical in shape, the contents of these spheres should be something different from the cytoplasm. To this hypothetical substance he gave the name of " Apparatinhalt " but he was not sure whether this was actually in contact with the cytoplasm in the case of half-moon or batonette shaped Golgi bodies. He further suggested the possibility that in living cells the lipoid structures normally formed closed containers, spherical or tubular in shape, inside which the " Apparatinhalt " was enclosed. Bowen showed that the idiosome and the " Apparatinhalt " were one and the same thing and in a series of papers convincingly demonstrated that the acrosomal rudiments develop within the idiosomic mass. He (1926 *d*) remarks: " This fact makes it very difficult to connect their origin with anything but the Golgi complex, more especially the idiosomic portion." Such being the case, the idiosome or the chromophobic part should play an important part in the production of secretory granules in vertebrate gland cells also, if we have to compare the process of production of secretory granules to that of the acrosome. This fact does not seem to have been considered at all by most cytologists and the few who saw a differentiation of the Golgi network into chromophilic and chromophobic regions interpreted these areas as artifacts. Some who describe the Golgi apparatus as canalicular or tubular do not state whether the areas where the secretory droplets originate are to be considered as the idiosome. The whole subject is thus in a confused state and hence I shall analyse here the results which bear on the problem in question. I should like to state my conviction even now that the process of secretion in gland cells is identical in both vertebrates and invertebrates as could be evidenced from the extra-ordinary similarity in the behaviour of the Golgi apparatus in the serous salivary gland cells of lower and higher animals, a similarity not easily to be accounted for, unless there is some causal connection between the Golgi apparatus and the type of granules produced in these cells (Bowen, 1926 *a*).

Does such a connection end with the relationship of the secretory granules to the distribution of the Golgi apparatus or is it seen even in the structure of the same cell organ ? I believe that the similarity of secretion phenomena is perfect even to minute details of structure of the Golgi apparatus. The differentiation of a clear space seen by Bowen in the pancreas of the salamander *Triturus* (*Diemyctilus*) *viridescens* (Fig. 105, Pl. 9, 1926*a*)—which was also seen by him in the older stages of the pancreas cells of *Cryptobranchus* (Bowen, 1924)—is dismissed as curious freaks of technique because he is sceptical concerning the vacuolated conditions in the middle stages of secretory activity. The above scepticism about the appearance of the chromophobic region inside the strands of the Golgi network, in relation with which no chromophobic component has been demonstrated, taken in conjunction with the fact that the acrosome almost always arises in relation with the idiosome appears contradictory. The network-like Golgi apparatus should have evolved from discrete bodies of invertebrates and hence the chromophobic component should be masked in those networks where visible differentiation into the two regions has not been noticed. Naturally we expect the masked idiosome to be differentiated when the Golgi apparatus becomes active. On this basis, if the Golgi network has a masked idiosomic core, it should become visible when secretory activity is at its height and the vacuolated conditions which Bowen dismisses as artifacts apparently represent the differentiated idiosome.

Passing now to cases where suspicion of an idiosome in relation with the outer border of the networks existed, a critical study shows that it had no material existence. Bowen (1924) mentions in the case of the Golgi apparatus of the pancreas of *Cryptobranchus* and the goblet cells of *Molge* that when the impregnation was delicate but sharp, the strands were very thin, and that there was an accompanying diffuse colouration as figured by Nassonov (1923) in the pelvic gland cells. He suggests : " Whether this is to be taken as an indication that the strands of the Golgi network are differentiated into a delicate cord of Golgi material proper, which is accompanied by another, the idiosomic substance, I am not prepared to say, but satisfactory proof of such a composition would be of great interest." The origin of secretory granules is described and figured by Bowen as taking place inside osmophil material of the strands as shown in his figures 8, 11, 12 and 13. The strands of the Golgi network are vesiculated and Bowen considers that these vesicles represent the earliest visible secretory granules. It should be mentioned here that the vesicles appear when the secretory activity begins and according to Bowen : " The formation of these vesicles in the goblet cells seems to be responsible in part for the reticulated

development of the Golgi network as noted above, and in the pancreas of *Cryptobranchus* I have noted a similar tendency towards similar reticular conditions." The secretory granules in the pancreas separate early from the Golgi apparatus and grow to their mature size in some other region of the cell. The further growth of the granules is provided for, by the contribution to each granule of a small piece of the original Golgi complex. Bowen says: "The clear zone located between the granule and the osmiophilic substance may be comparable to the idiosomic region of the Golgi complex in which the acrosomal vesicles are known to differentiate." The idiosomic component has been suspected by Bowen to be in contact with the outer border of the meshes of the network. The secretory granules arise in the substance of the Golgi reticulum and their escape into the cytoplasm should be by rupture of the Golgi substance. In the process they apparently carry a bit of the Golgi material and it is between this and the granule that there is an apparent idiosomic substance. Hence if we have to accept in full Bowen's interpretation, the Golgi bit attached to the granule should have theoretically a chromophobic area on either side. From Bowen's description it does not appear to have a chromophobic area on the side directed towards the cytoplasm and hence the idiosome seems to be between the chromophilic portion and the secretory droplet. Extending this interpretation it appears, that the Golgi network in goblet cells of *Molge* and pancreas cells of *Cryptobranchus* do not have any visible chromophobic areas in relation with them in the early stages of secretory activity and that when the apparatus begins to secrete, chromophobic areas are differentiated in the form of clear vesicles inside the Golgi substance. In these chromophobic areas it is, that the secretary granules first originate (see also Nassonov, 1924) and when they are liberated by rupture, they carry off pieces of the Golgi apparatus which have the chromophobic areas between the granule and the lipoidal part as in acrosome formation in spermatogenesis. Thus it becomes clear that vesiculisation occurs in the active stages of secretory synthesis and serves to explain some of the observations of Bowen which he himself could not interpret. In the epididymis Bowen did not find the Golgi apparatus as hollow tubes as figured by Nassonov in 1924. But in such cells he describes the substance of the Golgi apparatus as spun out in cords and plates which may be perforated in fantastic ways (Fig. 45, Pl. 26, 1926 *c*). Sometimes the networks appeared as if composed of a sheet of minute bubbles the walls of which were blackened, or like that of a delicate network with minute vesicles in the meshes (his Figs. 45, Pl. 26, and 50, Pl. 27). In addition he found another "closely related appearance in which the blackened Golgi contours were bordered externally by a light

zone similar to the one which in other cases appears on the inner border of a blackened contour. These various appearances are best shown in cross-section (Figs. 33, 48, Pl. 26; Figs. 66, 69, Pl. 27 and from the rabbit Figs. 71–73); but one type at least can also be very clearly demonstrated in longitudinal section (Figs. 39, 40 and 42, Pl. 26)." Bowen has been unable to trace any connection between the light areas and the secretory droplets. It will be seen from Bowen's description and figures, that tubular and vesiculated networks have been noticed only when the cell was actively synthesizing secretory products. These observations of previous workers led me to investigate the question whether such a differentiation occurs during secretory activity in any other type of gland cell. In the liver cells Cramer and Ludford (1926) figure such a condition but as in a later paper by Ludford (1928) some of the facts in the previous paper are not substantiated, I decided to investigate the structure of the Golgi apparatus in the liver cells of the tree frog *Rhacophorus*.

Previous Work on Liver Cells.

Holmgren, in 1904, made some observations on the so-called trophospongium in liver cells and he observed a highly complex network. Stropeni in 1908 contradicted Holmgren's results and showed a simple network between the nucleus and the bile capillary in amphibian liver cells. Kolmer (1916), Pascaul (1924) and Pappenheimer (1916) describe imperfect Golgi apparatus in the kitten, rat and mice embryos. Nassonov (1926), Makarov (1926), and Glasunow (1928) have recently studied the effect of intra-vital staining on liver cells. Bowen (1926) in his masterly survey of the Golgi apparatus in gland cells gives a brief account and Cramer and Ludford (1926) come to the conclusion: "The osmophil canaliculi in this latter condition resemble in appearance and arrangement so closely the intracellular bile canaliculi as figured by Kupffer and reproduced in Schafer's *Essentials of Histology* that one cannot but consider them as identical structures." In this connection, their description of Fig. 9 will be of interest. "It will be observed that in Fig. 9 one of the canaliculi which is connected with the intercellular bile capillary (*bc*) can be seen to consist of a colourless interior surrounded by an osmophil substance (*os*)." Basing the usage of the term osmophil canaliculi on the above description it will be seen from their paper that Figs. 1, 2, 3 and 4 do not come under this category at all. In Figs. 5 and 6 osmophil filaments and canaliculi are seen, while in their pictographic summary of secretion osmophil canaliculi are shown only in Fig. 15. Yet these authors use the term osmophil canaliculi throughout their description whether these may be actual canaliculi or mere filaments.

That they use the term osmophil canaliculi to mean osmophil tubes will become amply clear by their conception "that in the liver cells the bile constituents appear as a secretion within the Golgi apparatus which, in the process of secretion, first enlarges and then fragments. The fragments are dispersed through the cytoplasm and reach the periphery where they pass their contents into the inter-cellular bile capillaries." Bowen describes in the liver cells of the cat large numbers of secretory granules that stain sharply with acid fuchsin. No such granules are described by Cramer and Ludford and if we have to accept their interpretation of the quantity of bile components formed in the liver as that contained only in the osmophil canaliculi, it should be little indeed. Moreover, the necessity for the rupture of the Golgi apparatus is not clear. Rupture of the Golgi apparatus should necessarily be followed by escape of the bile components into the cytoplasm and how these escaped droplets reach the intercellular bile capillaries is not clear from their descriptions. A look at their Figs. 10–15 will surely indicate that there is an enormous increase in size of the cytoplasm and the Golgi apparatus. If the bile constituents are contained only in the osmophil strands, it is not at all clear why the cytoplasm should correspondingly increase in size, for, in most gland cells increase in volume of the cell is due more to accumulation of secretory granules than due to actual increase in volume of the cytoplasm. According to Bowen (1926 *d*) actually during the active secretory period the general cytoplasmic content of the cell as a rule is not increased and indeed becomes finally so attenuated in some gland cells as to be demonstrable with difficulty. If the secretion is contained only in the pieces of the Golgi apparatus and if the contents of the pieces are passed directly into the inter-cellular bile capillary, it is a little difficult to conceive how a reduction in size of the cytoplasm and Golgi apparatus takes place. The very fact of a return to the quiescent condition as shown in Fig. 10 requires either the degeneration of a large portion of the cytoplasm or the disintegration and extrusion of most pieces of the Golgi apparatus. In his paper on the effect of vital staining Ludford (1928) describes the Golgi apparatus and mitochondria in normal liver cells. Though the results of both papers bear on the liver cells of the mouse, the shape and structure of the Golgi apparatus and mitochondria described in the later paper are entirely different from what has already been recorded by him. Cramer and Ludford figure the mitochondria in their text-figures 5, 7 and 8 as vesicluar but Ludford (1928) represents them as filaments in his Fig. 15. The Golgi apparatus in normal and vitally stained liver cells are represented merely as osmophil filaments though Cramer and Ludford figure canals with osmophil walls in their Figs. 9 and 15.

Technique.

Few of the earlier workers seem to have succeeded in getting good impregnations of the Golgi apparatus in the liver cells by the silver nitrate or osmic acid methods. Bowen (1926 *a*) had partial success and Cramer and Ludford (1926) on the belief that glycogen being washed out of the cells by watery fluids distorts the morphological appearance of the Golgi apparatus, avoided the difficulty by rendering the liver cells free or almost free from glycogen by various devices such as feeding with thyroid gland, injection of β-tetrahydronaphthylamin, exposure to cold, injection of insulin and ligature of the bile duct. Being not quite sure whether such devices may not have some effect on the structure of the Golgi apparatus, I depended entirely on material from animals which were not subjected to any of the above treatments. Da Fano, Cajal and Ayoyama's silver nitrate methods were thorough failures. Fixation times were varied from 3 hours to 48 hours and silver impregnation up to five days. Some yellow strands occupying the position of the Golgi apparatus were often seen and some experiments were conducted to see whether these strands could be induced to take up silver. For this purpose slides were brought down through alcohols to water and kept in a jar of Da Fano's fixative for periods ranging from 2 hours to 24 hours. Later they were washed in distilled water and passed on to silver nitrate for periods ranging from 12 hours to 48 hours. Then after washing quickly in distilled water the sections were reduced in Cajal's reducing fluid for 6–8 hours. Some impregnations were obtained of the Golgi apparatus, but it had a shrunken appearance. The silvering was capricious and for a study of the structure of the Golgi apparatus the preparations were useless. Still the fact that the Golgi apparatus may be impregnated in sections offers a possibility of devising some silver technique which could be used on sections if silvering before dehydration and embedding was not successful.

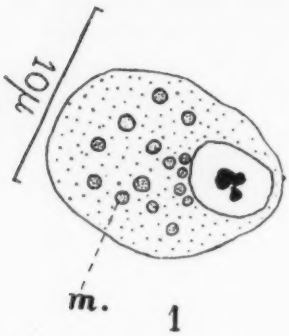
A modification of the Mann Kopsch method proved useful. Small pieces of the liver were kept for 5 minutes in osmic vapour and then fixed in corrosive-osmic mixture containing one part of saturated solution of mercuric chloride in normal saline to 1·5 parts of 2 per cent. osmic acid. It was accidentally discovered that fixation for 8 hours and osmication for 4 hours at 42° C. and continued at 36° C. for 12 days blackened the Golgi apparatus alone, whereas osmication at 42° C. for 8 hours and continued at 36° C. for 12 days gave pictures of both the Golgi and the mitochondria. In the latter preparations it was found impossible to remove the blackening from the mitochondria alone. All materials fixed in Mann Kopsch when sectioned were thoroughly black and after several trials a very good method

for bleaching the slides was devised. Treatment with either hydrogen peroxide or potassium permanganate and oxalic acid is not entirely under the control of the operator and the removal with turpentine took 5 to 6 days. By a combination of the two methods it was found possible to treat a large number of slides getting proper differentiation in most of them. Sections were first treated with potassium permanganate and oxalic acid, or hydrogen peroxide till the cytoplasm became brown. They were then upgraded, passed into jars containing turpentine. The best results were given by the syrupy venetian turpentine generally used for mounting. It was found that 24 to 36 hours in turpentine generally gave good results. The de-osmication is slow and examination of slides at one hour intervals will give the operator an idea of how far the de-osmication had proceeded. For the mitochondria, Champy's fixative proved uniformly successful but fixation time had to be extended to 36 or 48 hours and mordanting to 4 days. In Champy the bile components never had a granular form, but occurred in cells as unstained or lightly stained areas. The fixation of the secretion granules was fortuitous and unlike the cat liver cells, they never took the acid fuchsin stain. When acid fuchsin was followed by aurantia, they were lightly tinged. In unstained sections, they were yellow and could be just made out after careful examination. Material was also fixed in Bouin, Bouin-Duboscq and corrosive acetic. Ludford (1928) shows in his Fig. 14 a metaphase. In text-books of histology it is mentioned that mitotic figures are not common in normal liver cells and my experience in the liver cells of *Rhacophorus* confirms these observations. Division of cells is by amitosis and even this was rare in the material. Fat droplets occur rarely in the material (Fig. 5) but unfortunately in these cells the Golgi apparatus was not fixed at all and hence the relation of fat to other cytoplasmic inclusions, if any, could not be studied.

Observations.

Mitochondria.

In the smallest non-secreting cells (Fig. 1) the mitochondria occur as vesicles. In the slightly larger cell shown in Fig. 2 the mitochondria are filamentous. It will be seen that there are some spherical mitochondria also in the cell. I have not been able to make out in this particular instance whether they are transverse sections of filamentous mitochondria or whether they are stages in the conversion of the vesicle into the filamentous type. Unfortunately, the vesicular form is not seen after the stages shown in Fig. 1 and no core to the filamentous mitochondria have been observed in spite of repeated experiments. In later stages, the granular



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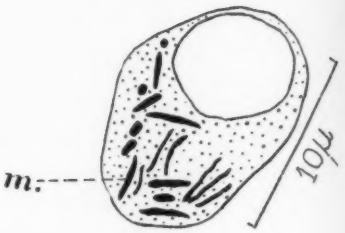

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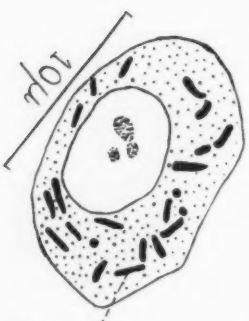
form of mitochondria seen along with the filamentous type seem definitely to be cross-sections of filamentous ones, for very rarely cells may be seen in which all the mitochondria are filamentous. Thus in Fig. 5 (in which secretion is not shown) most of the mitochondria are filamentous. The mitochondria increase in number and size and do not appear to be collected in any particular portion of the cytoplasm. The earliest secretion products are not seen in Champy fixed material and in Mann Kopsch they have no relation to the mitochondria. In Figs. 3, 4 and 6, the increase in number



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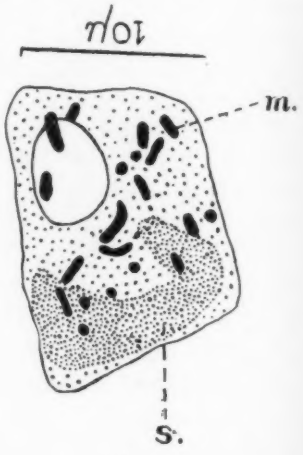

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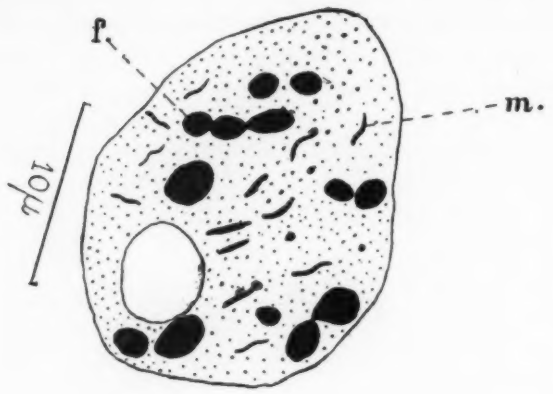
could be noticed and a careful examination of the cells reveal a few mitochondria which are longer than the others. I believe that these may probably represent mitochondria which are about to divide transversely into two. Actual division has not been observed but as most filamentous mitochondria



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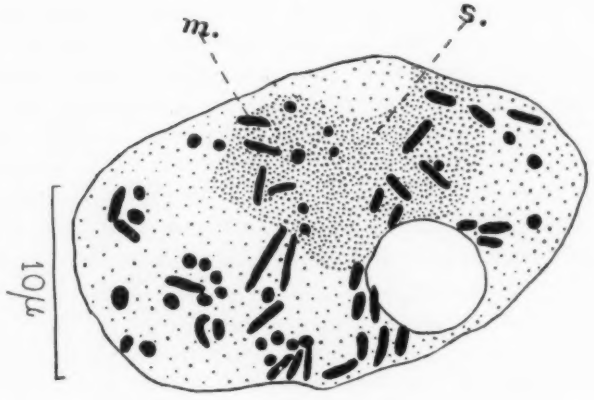

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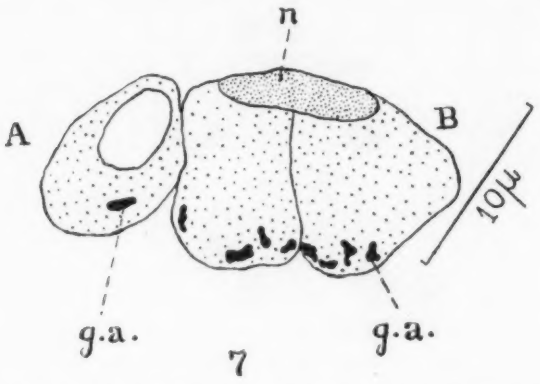
are almost uniform in size and as these long filaments are rare the probability of their dividing transversely is strengthened. Secretion may be seen in Figs. 4 and 6 as unstained masses. Though Champy's fluid does not fix the secretion it does not alter its position in the cell, for, it is always found near the cell wall on the side near an inter-cellular bile capillary.

Golgi Apparatus.

Dictyokinesis.—During amitotic division dictyokinesis was observed. But, the size of the cells was rather big giving one an idea that the quiescent cell after the extrusion of the formed secretion was definitely smaller than

a cell formed by amitosis. I am led to believe, from the stages seen by me, that a growth of the cell takes place prior to division. In Fig. 7 are



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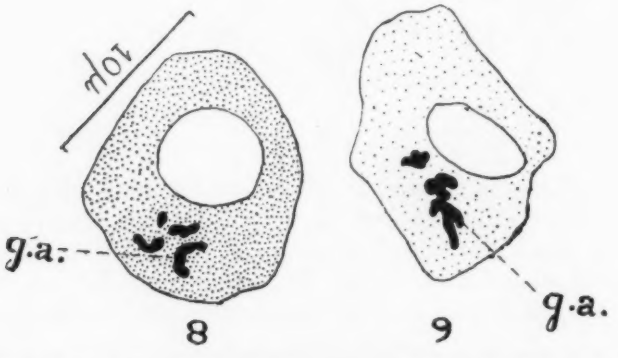
three cells and the one at A seems to be in a quiescent condition. A Golgi network does not occur and there is only a single rod-like Golgi mass. There is no differentiation into chromophilic and chromophobic regions, but the structure seems to be lamellar, as somewhat different appearances are seen when the objective is raised or lowered slightly. In Fig. 8 is the next stage, where the Golgi pieces vary in number from three to six. No intermediate stages between Figs. 7 and 8 were obtained. In Fig. 9 is shown the Golgi apparatus in which the individual pieces in Fig. 8 seem to have joined together. As in the case of Figs. 7 and 8, in Fig. 9 also no differentiation into



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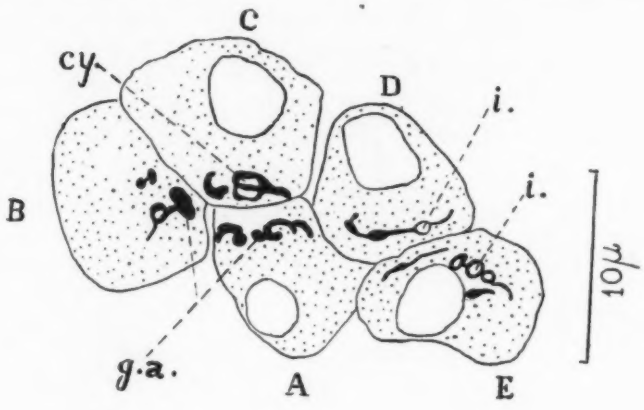
chromophilic and chromophobic regions are distinguishable. In Fig. 10 is drawn a group of five cells. The inter-cellular bile capillaries are not visible and the Golgi apparatus is seen as a branched structure in A. In B a space

is seen in the substance of the Golgi apparatus, but in the actual cell, the space appears to be that enclosed by the union of two strands. These lie in different planes and in the figure the space appears as if inside the lipoidal substance of the Golgi. In Fig. 10 C also the space in the Golgi apparatus has nothing to do with the chromophobic areas to be described hereafter. In D and E in Fig. 10 the spaces seen are not due to two strands, but are



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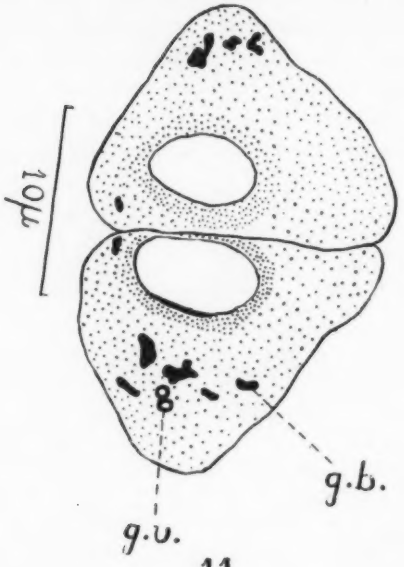
actual chromophobic areas differentiated. On raising or lowering the objective the blackened edges come closer together until only a thin thread-like structure is seen, which lies in the middle of the original place where the vacuole was seen. I would like to stress here that it is easy to distinguish between the idiosome differentiated inside the substance of the Golgi apparatus and the space enclosed by two strands of the Golgi network. It is at this stage that amitotic division takes place. Even in this innumerable variations were observed. Without going into a description of the various types, I shall content myself by stating that the Golgi network seems to break up into a number of pieces. I have also considered the possibility of the increase in number of the pieces shown in Fig. 7 A but it appears, from the cells shown in Fig. 11 especially from the occurrence of vesicular Golgi, that the probability is more of a network which has differentiated a chromophobic part breaking into discrete pieces. In Fig. 7 B the nucleus does not seem to have divided but the cell wall which has already developed has divided the Golgi pieces roughly into two groups. Fig. 11 is interesting in that the cells formed are bigger than those shown in Fig. 7 at B. The nuclei of the cells lie near each other on either side of the newly formed cell



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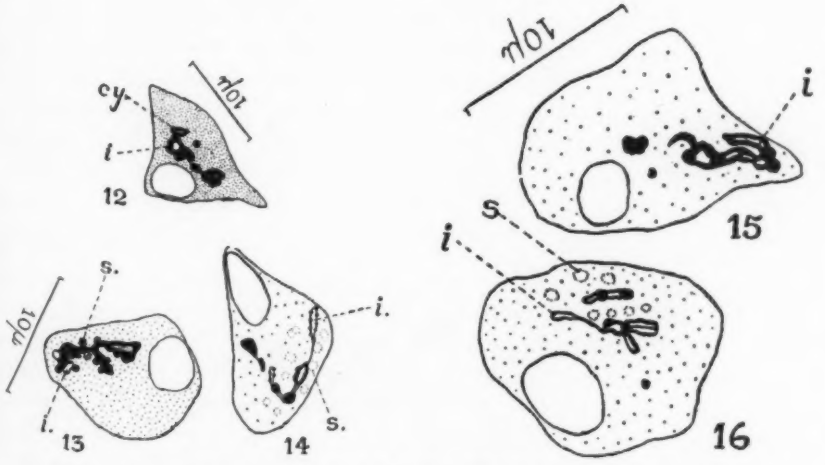
wall, but the Golgi pieces are found at opposite poles. The division of the Golgi mass does not appear as equal as may be expected from the definite orientation of these bodies. Such examples are very rare and hence I merely record the fact that such regular orientation takes place in some cells undergoing amitosis. It will be seen that in one of the cells in Fig. 11, Golgi vesicles are seen. The fact will, I think, be admitted that the chromophobic part not seen in the earliest quiescent cells appears in the Golgi vesicles shown in Fig. 11.

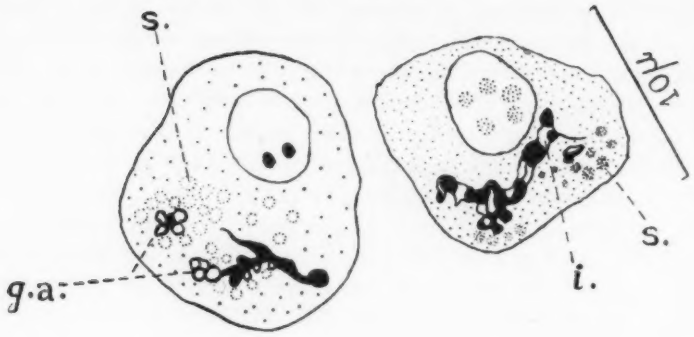
The Behaviour of the Golgi Apparatus during Secretion of Bile Components.

The network shown in Fig. 10 forms a good beginning for the study of the Golgi apparatus during secretion. In D the network has bleb-like swellings in one portion and a differentiated chromophobic part in the other. Slight swelling of the osmophil strands has been noted in the majority of the cases where the network seems to have no differentiated chromophobic part. In Fig. 12 where the plane of section seems to pass through a narrow region of the cell, bleb-like swellings of the osmophil strands can be seen. In the place marked *i* the idiosome seems to be differentiated and at *cy* the space enclosed is by two strands which are not seen together at one position of the objective. This condition is followed by stages in which the secretory

granules could be made out in relation with the surface of the Golgi strands. In Fig. 13 the chromophobic part in that portion of the Golgi apparatus near the nucleus and shown stippled seems to be in the process of differentiation, while at the other end differentiation is complete. Secretory granules in this particular cell are seen near those regions of the apparatus where a chromophobic part has not been differentiated. In Fig. 14 the differentiation of the chromophobic part has advanced a step further. Secretory granules are seen in relation with the network in those regions where a chromophobic part has been differentiated and also in that where a differentiation is lacking. At this particular stage a number of pictures varying from each other is obtained. In Fig. 15 differentiation had occurred but



no secretory granules were seen and in Fig. 16, the apparatus occurs as two pieces each with chromophobic areas differentiated in some regions. The apparatus in Fig. 17 also occurs as two pieces which have a vesiculated appearance. In this cell more secretory droplets were seen near the surface of Golgi in the regions where a differentiation of the idiosome had taken place. The Golgi apparatus in Fig. 18 has differentiated chromophobic areas interspaced by regions where no differentiation has occurred. Few granules were observed in this cell and none at all in close relation with the network. But they were all found in the region of the cytoplasm between the network and the inter-cellular bile capillary. A deep impregnation in which the secretory granules were light brown is shown in Fig. 19. No chromophobic areas were distinguishable and the clear area seen is only the space enclosed by two strands. Some secretory granules were very



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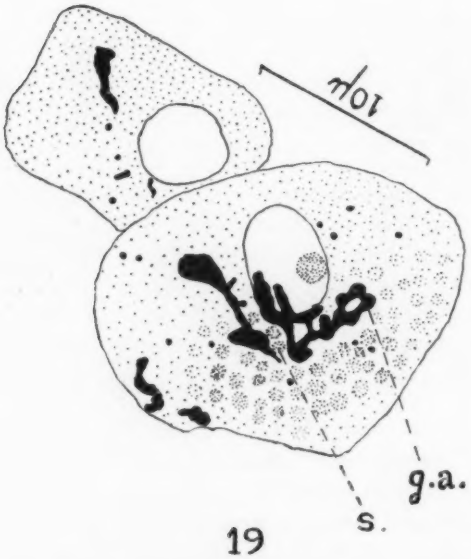

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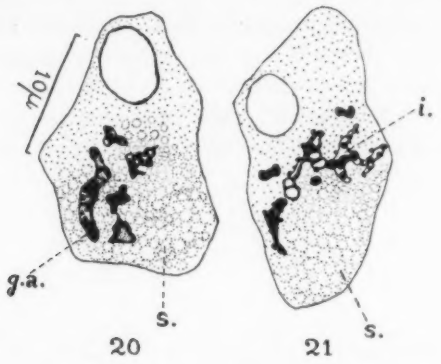
clearly seen between the two strands of the apparatus lying near each other. Sometimes the nuclear membrane was impregnated by osmic acid very lightly and then it appeared brownish. Such an example is seen in Fig. 20. The Golgi apparatus in this section appeared as a number of pieces. In the stippled region inside the substance of the Golgi the chromophobic area was deep brown, while in the clear areas seen in other regions of the apparatus it was yellowish. Large numbers of secretory granules occur in cells at this stage and that region of the cell where these occur is different



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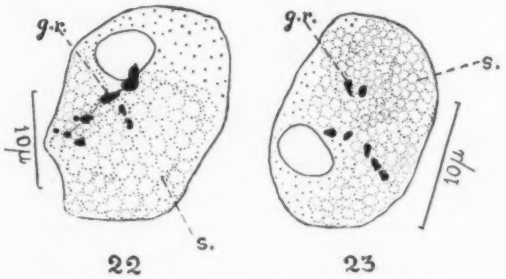
in colour from the rest. Individual granules could be just made out and the Golgi apparatus lies embedded among the secretory granules. Hereafter one could not speak of individual secretory granules in close relation with the Golgi apparatus. Large numbers of granules appear as if pasted on the surface of the meshes. The final stage in the differentiation of the chromophobic area inside the network is shown in Fig. 21. The clear areas seen are the chromophobic areas but the network is not tubular as figured by Nassonov in the case of the epididymis (Taf. III, Figs. 15, 16, 17, 19 and 22,



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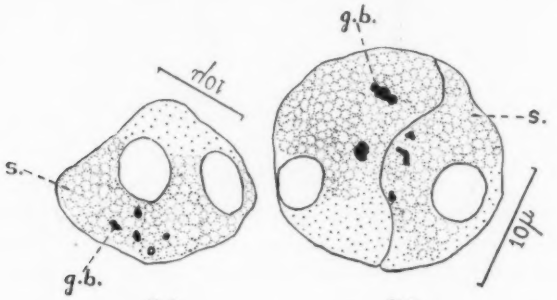
1924). In the liver cells of *Rhacophorus* the chromophobic areas are separated by chromophil regions where differentiation has not occurred. The secretory droplets occur generally only in the region of the cell between the intercellular bile capillaries and the Golgi apparatus. Never are they seen to occupy the whole cell area. After the formation of the secretory granules, the Golgi having completed their work for the moment undergo fragmentation. Appearances shown in Fig. 22 are quite common and it appears that rupture of the Golgi apparatus takes place in the regions where the chromophobic areas have been developed. The apparatus has now the form of a number of osmophil masses connected together by very thin

osmophil threads. These threads also finally disappear and we get a number of osmophil masses as shown in Fig. 23. These irregular chromophil structures become less and less in number as could be made out from Figs. 24 and 25. During the dissolution of the major portion of the Golgi, appearance of a number of vesicles along with osmophil rods and filaments is quite



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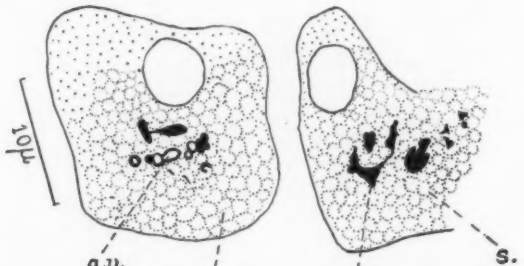
common (Fig. 26). But all these vesicles disappear leaving only osmophil structures of irregular shape which do not seem to have any chromophobic component. Many instances of rupture of the cell to release the bile components were seen in both control preparations as well as Champy and Mann Kopsch. Such an example is shown in Fig. 27. It will be seen that the



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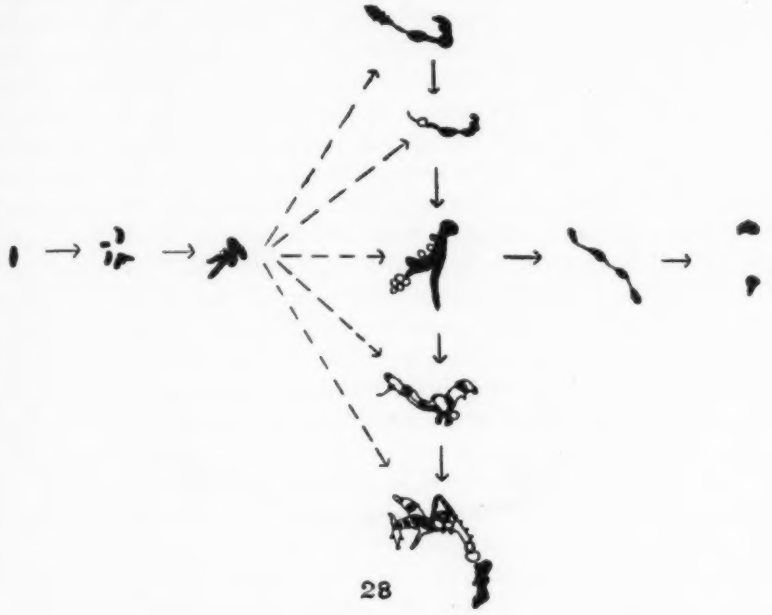
Golgi apparatus has broken up and portions of it are already being extruded. I am quite sure that these appearances are not due to bad fixation or kindred causes, but whether rupture is the method by which bile components are sent out I cannot definitely say. In the absence of critical evidence I feel that it is safer to assume that these cases of rupture represent the worn out cells which go to pieces eventually to be lost in the general glandular product, their places being taken up by new cells.

The changes in the shape and structure of the Golgi apparatus are shown pictographically in Fig. 28.



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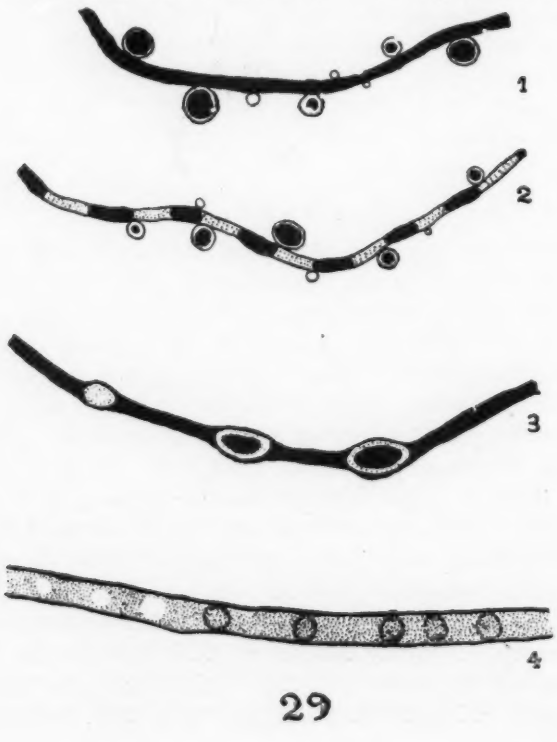
Discussion.

In order to assign any particular function to a cell component its structure should be well understood. This lack of a clear understanding of the structure of the Golgi apparatus has led to several interpretations of the mechanism of its working. Analysing the various theories of the function of the Golgi apparatus one comes across conceptions in which the same author contradicts the results of his previous paper without explaining the cause for such a procedure. Thus Bowen confuses between two processes, namely, origin of secretory granules inside the substance of the Golgi apparatus as in the pancreas of *Cryptobranchus* (Bowen, 1924) and origin of secretory granules in relation with the outer border of the Golgi strands or plates. Ludford (1925) and Cramer and Ludford (1926) describe secretion originating within osmophil canaliculi, whereas Ludford (1928) describes trypan blue droplets originating in close relationship with the outside of the osmophil filaments. Similarly Nassonov (1924) describes in the pancreas and epididymis of the mouse secretion originating inside tubular strands, while in glandula vesicularis they originate in relation with the apparatus

but not inside the substance of the strands. From the positional relationship between the Golgi apparatus and the trypan blue droplets Nassonov comes to the conclusion that the function of the Golgi apparatus is a selective concentration of definite substances, while Ludford goes a step further and says that synthesis by enzymes occur at the mitochondrial-cytoplasmic interface and that the Golgi apparatus plays only a physical rôle, namely, condensing the products elaborated by the enzymes secreted by the mitochondria. I was surprised how such a hypothesis would explain the production of secretion in the liver and the epididymis (Ludford, 1925 ; Cramer and Ludford, 1926), where secretions actually originate inside the strands. An attempt at correlation of the results obtained by Ludford is rather confusing. This confusion regarding the function of the Golgi apparatus and mitochondria, due mainly to a lack of clear knowledge of the structure of the Golgi apparatus, is also seen in a recent paper by Duthie (1934) on pancreas cells. Nassonov, in 1924, showed in his Figs. 29 and 30 the earliest secretion granules taking their origin inside the strands of the Golgi apparatus. Without proving beyond doubt that the region where the earliest



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secretion granules arise contain only mitochondria, with no extension of the Golgi apparatus, Duthie comes to the conclusion that the prozymogen granules are first formed in contact with the mitochondria and that they later pass on to the Golgi zone and get transformed into zymogen. The relation between the mitochondria and prozymogen is not established as the following observations of his would show. " The relationship of the newly formed granules to the mitochondria is not always as clear as one might expect. There is no doubt that some of the mitochondria may remain unstained by Janus Green, so that the appearance of a granule in one area of the cell not occupied by visible mitochondria is no proof that such a relationship does not exist. There is no doubt, however, that the granules arise, if not in actual contact with the mitochondria, at least a little distance from them so that there is no question of either bleb formation or fragmentation occurring as described by previous workers, Saguchi (1930), Morelle (1925), Horning (1925)." Thus even the intimate relationship between the prozymogen and mitochondria being not proved, Duthie does not also explain the appearances seen by Nassonov. If the vesiculated appearances noted by Bowen and Nassonov are not the earliest secretion droplets, how are these appearances to be explained ? If Nassonov had described the origin of the earliest secretory droplets on the surface of the Golgi apparatus, it is true that the probability of the prozymogen arising in the region of the mitochondria and later migrating to the region of the Golgi may be expected. Any theory postulating the origin of secretion in the pancreas or liver cells in relation with the mitochondria should give convincing explanations of the origin and appearance of the vacuoles in the strands of the Golgi network. This Duthie has not done.

Is there any way out of this confused state of our knowledge regarding the structure of the Golgi apparatus ? The solution is at hand if only one tries to correlate the structure of the network with that of the discrete bodies of invertebrates. The conception that the idiosome is masked in some networks and should become differentiated during secretory activity in some cases seems to have some justification. Parat (1930) figures his *chondriome actif* giving rise to bleb-like swellings which later differentiate a space inside. This process, according to him, may proceed further and may produce even tubular strands (his Figs. VI and IX). Keeping in mind the above conception, all observations recorded up till now may be brought under four types (Text-Fig. 29). In the first, the network has no visible chromophobic area and the secretory granules arise touching the strands of the Golgi network (Bowen, 1926 *d*, Fig. 3, p. 441). In the second, the chromophobic areas are differentiated in various portions of the network during secretory activity

but the granules arise in relation with the outer surface of the Golgi apparatus (Bowen, 1926 *c*, Figs. 70–88 ; and the results presented in this paper). In the third type, the chromophobic areas are differentiated during the activity of the apparatus and the secretory granules originate inside these spaces (Bowen, 1924, Figs. 8, 11, 12 and 13). Liberation of these granules have necessarily to be by rupture of the strands and often they may carry a piece of the Golgi material. Finally, the whole apparatus is tubular and secretory granules arise inside these tubes to be released either by rupture or through the open ends of the tubes (Nassonov, 1924, Figs. 15, 16, 17 and 22).

The differentiation of the Golgi network into chromophilic and idiosomic regions renders comparisons of the secretions of various materials by the apparatus in vertebrates and invertebrates—where they have entirely different shapes—more logical. It is not quite necessary to consider that the secretory granules should arise inside the chromophobic areas, for in order to understand the mechanism of working of the apparatus we have to conceive of enzyme intermediaries. Subramaniam (1937) has shown that in vesicular Golgi bodies of *Meretrix* eggs the neutral red stains first the chromophobic interior and later the dye is segregated into vacuoles around the periphery of which the Golgi vesicles with clear interiors are now arranged. Bowen in 1924 showed that in the pancreas of *Cryptobranchus* the secretory granules are found inside the meshes of the network. In *Meretrix* neutral red staining material comes out through the lipoid membrane, while in *Cryptobranchus* raw materials pass in. Thus both the processes have been observed and it is not at all necessary that the visible granules should originate inside the chromophobic areas. What is more important appears to be the presence of the chromophobic area in vertebrate Golgi apparatus enabling one to compare it with that of the discrete bodies of invertebrates in function and suggesting the derivation of one from the other. It will also be seen that the above observations rule out the mitochondria having any active part in the visible production of secretory granules. It is true that along with the nucleus, nucleolus and ground cytoplasm it may supply the Golgi with raw materials for the production of granules, but the very fact that in some cases the secretory granules actually originate inside the chromophobic areas in the substance of the Golgi apparatus suggests, that the cell inclusion which synthesizes materials into the visible form is the Golgi apparatus.

Summary and Conclusions.

It is suggested that the chromophobic or idiosomic component of vertebrate somatic cells occurs as a core in the Golgi substance. In the liver cells

of *Rhacophorus* during activity, the core which is masked in the early stages becomes differentiated inside the substance of the apparatus in various regions. Rupture and disintegration of the apparatus takes place in those regions where chromophobic areas have been differentiated resulting in the formation of osmophil masses which have no visible chromophobic component. The demonstration of a chromophobic or idiosomic component in the vertebrate Golgi apparatus renders the comparision of secretion of various substances by the apparatus in vertebrates and invertebrates more logical.

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I wish to record here my gratitude to Professor R. Gopala Aiyar for his valuable advice, helpful criticisms and constant encouragement. My thanks are also due to the University of Madras for awarding me a Research Fellowship.

BIBLIOGRAPHY.

Bowen, R. H. .. .. "On a Possible Relation between the Golgi Apparatus and Secretory Products," *Amer. J. Anat.*, 1924, **33**, 197–216.

———— .. .. "Studies on the Golgi Apparatus in Gland Cells.—I. Glands Associated with the Alimentary Tract," *Quart. Jour. Micr. Sci.*, 1926 *a*, **70**, 75–113.

———— .. .. "II. Glands producing Lipoidal Secretions," *ibid.*, 1926 *b*. 193–217.

———— .. .. "III. Lachrymal Glands and Glands Associated with the Male Reproductive System," *ibid.*, 1926 *c*, 395–419.

———— .. .. "IV. A Critique of Topography, Structure and Function of the Golgi Apparatus in Glandular Tissue," *ibid.*, 1926 *d*, 419–51.

———— .. .. "Golgi Apparatus—Its Structure and Functional Significance," *Anat. Rec.*, 1926 *e*, **32**, 151–93.

Cajal, R. .. .. .. "Algunas variaciones fisiologicas y patologicas del apparato reticular de Golgi," *Trab. del. Lab. Inv. Madrid*, 1914, **12**, 127–227.

Cramer, W., and Ludford, R. J. "On the Cellular Mechanism of Bile Secretion and its Relation to the Golgi Apparatus of Liver Cell," *J. Physiol.*, 1926, **62**, 74–80.

Duthie, E. S. .. .. "Studies in the Secretion of the Pancreas and Salivary Glands," *Proc. Roy. Soc. London*, (B), 1934, **114**, 20–48.

Glasunow, M. .. .. "Beobachtungen an den Mit Trypanblau vitalgefarbten Meerschwinchen—I. Morphologie der Trypanblau-ablagerungen in einigen Epithelzellen," *Zeit. f. zellf. u. mikr. Anat.*, 1928, **6**, 773.

Hirschler, J. .. .. "Uber den Golgischen Apparat Embryonalerzellen," *Arch. f. mikr. Anat.*, 1918, **91**, 140–82.

Holmgren, E. .. .. "Beitrage zur Morphologie der Zelle—I. Verschiedene Zellarten," *Anat* Hefte., 1904, **25**.

Kolmer, W. .. .. "Uber einige durch Ramon y Cajal Uransilbermethode darstellbare strukturen und deren Bedeutung," *Anat. Anz.*, 1916, **48**, 506.

Ludford, R. J. .. .. "Cell Organs during Secretion in the Epidydymis," *Proc. Roy. Soc. London*, (B), 1925, **98**, 355–72.

———— .. .. "The Vital Staining of Normal and Malignant Cells.—I. Vital Staining with Trypan Blue and the Cytoplasmic Inclusions of Liver and Kidney Cells," *ibid.*, 1928, **103**, 288–301.

Makarov, P. .. .. "Beobachtungen uber den Golgischen apparat und die ablagerungen von Trypanblau in den Leberzellen verscheidener Wirbelthiere," *Arch. Russ. d'Anat. d'Hist., et d'embryol.*, 1926, **5** (Quoted by Ludford).

Nassonov, D. .. .. "Das Golgische Binnennetz und seine Bezeihungen zu der sekretion. Forsetzung. Morphologische und experimentelle untersuchungen an einige Saugetierdrusen," *Arch. f. mikr. Anat.*, 1924, **100**, 433–73.

———— .. .. "Die Physiologische Bedeutung des Golgiapparats im Lichte der Vitalfarbungsmethode," *Zeit. f. zellf. u. mikr. Anat.*, 1926, **3**, 472–502.

Parat, Maurice et Marguerite, "Essai D'Analyse Histochimique et Morphologique de la Zone deiGolgi,—Cellule de la Glande Pelvienne du Triton, Cellules Intestinales de Triton et d'Axolotl," *Arch. d'Anat. Microsc.*, 1930, **26**, 447–74.

Pascaul, J. A. .. .. "Appareil de Golgi du foie pigment des fibres musculaires cardiaque et lisse," *Trab. d. Lab. Rech. Biol. Univ. Madrid*, 1924, **22** (Quoted by Bowen).

Subramaniam, M. K. .. "Oogenesis of *Meretrix casta* with a suggestion as to the Nature of the Contents of the Neutral Red Vacuoles," *J. Morph.*, 1937, **61**, 127–48.

Subramaniam, M. K., and Ganapati, P. N. "Studies on the Structure of the Golgi Apparatus—I. Cytoplasmic Inclusions of a Gregarine parasitic in the gut of Lumbriconereies," *Cytologia* (In press), 1938.

Subramaniam, M. K., and Gopala Aiyar, R. "Two Methods of Formation of Dictyosomes from Vesicular Golgi Bodies," *Nature*, 1936 *a*, **137**.

———— .. .. "Some Observations on the Possible Mode of Evolution of the Network-like Golgi Apparatus of Vertebrate Somatic Cells from Discrete Golgi Bodies of Invertebrates," *La Cellule*, 1936 *b*, **45**, 61-73.

———— .. .. "An Analysis of the Shape and Structure of the Golgi Bodies in the Eggs of Invertebrates with a Note on the Probable Modes of Origin of the Network," *Proc. Ind. Acad. Sci.*, 1937, **5**, 142-168.

EXPLANATION OF FIGURES.

Key to Lettering.

cy.—The cytoplasm between two strands of the Golgi apparatus ; *f*—Fat; *g.a.*—Golgi apparatus ; *g.b.*—Golgi bodies ; *g.r.*—Golgi remnant; *g.v.*—Golgi vesicle; *i.*—Idiosome ; *m.*—Mitochondria ; *n.*—Nucleus; *s.*—Secretion.

Figs. 1 to 6 are from Champy and Figs. 7 to 28 from Mann Kopsch preparations.

Fig. 1.—A small quiescent liver cell showing vesicular mitochondria.

Fig. 2.—A slightly older cell with many filamentous mitochondria.

Fig. 3.—Mitochondria scattered throughout the cell.

Fig. 4.—Showing mitochondria and secretion.

Fig. 5.—A cell showing deposited fat and mitochondria.

Fig. 6.—Liver cell at the height of its secretory activity.

Fig. 7.—A. Showing Golgi apparatus in a quiescent liver cell.
B. Dictyokinesis. The cell wall has been formed but the nucleus has not divided into two.

Figs. 8 & 9.—Showing the formation of a complex Golgi apparatus from discrete bodies.

Fig. 10.—A group of cells at the beginning of secretory activity showing the Golgi apparatus. In D and E the idiosome has been differentiated inside the lipoidal material of the apparatus.

Fig. 11.—Amitotic division showing the almost regular orientation of the Golgi bodies. It will be observed that in the lower cell some Golgi vesicles are also seen.

Figs. 12, 13 & 14.—Three cells showing the differentiation of the Golgi strands in some regions into outer chromophilic and inner chromophobic regions. Secretion originating in relation with the apparatus may be seen in Figs. 13 and 14.

Figs. 15 & 16.—Further stages in the differentiation of a chromophobic part in the substance of the Golgi apparatus.

Figs. 17 & 18.—Secretion is seen arising in relation with the vesiculated portion of the Golgi apparatus in Fig. 17. In Fig. 18 areas where differentiation of the chromophobic regions have occurred are interspaced by areas where such differentiation is lacking.

Fig. 19.—Deeply impregnated Golgi apparatus in which no duplex differentiation is noticeable.

Figs. 20 & 21.—Show the final stages in the differentiation of an idiosome inside the substance of the Golgi apparatus. The portion of the cell between the nucleus and the inter-cellular bile capillary is packed with secretion.

Figs. 22 & 23.—Changes in the Golgi apparatus before the extrusion of the secreted bile components. Rupture and disintegration seems to occur in places where the chromophobic regions have been differentiated.

Figs. 24 & 25.—Cells packed with secretion showing few Golgi bodies, the others having disintegrated.

Fig. 26.—Vesiculated appearance of the Golgi remnants during the disintegration of the network.

Fig. 27.—Rupture and extrusion of the bile components and pieces of the Golgi apparatus.

Fig. 28.—A pictographic summary of the shape and structure of the Golgi apparatus in liver cells of *Rhacophorus*.

Fig. 29.—A diagrammatic representation of the different methods of association observed by different authors between the Golgi network and secretory droplets.

ON THE MORPHOLOGY AND IDENTIFICATION OF A TRYPANOSOME FOUND IN THE BLOOD OF *HEMIDACTYLUS BROOKI* GRAY.*

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and

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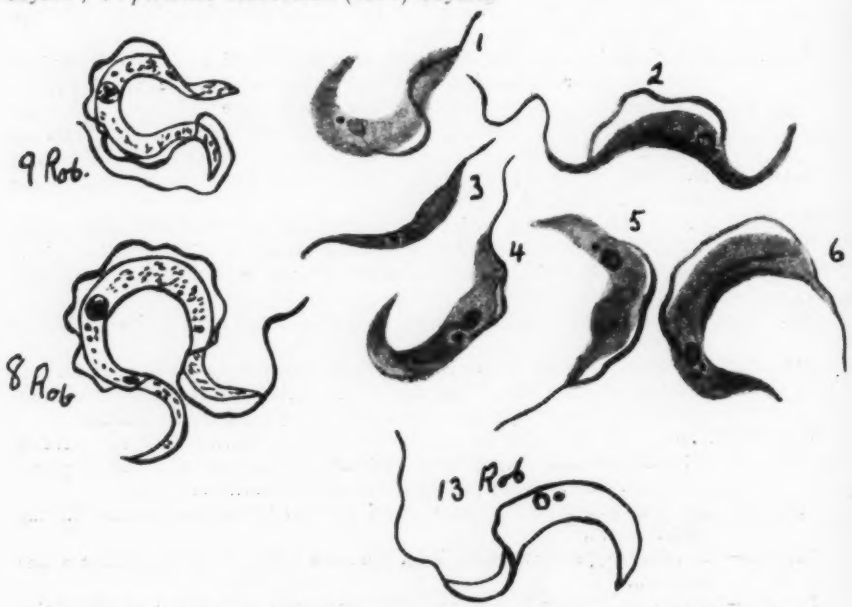
Received January 17, 1938.

The Trypanosomes hitherto described in the blood of lacertids of the genus *Hemidactylus* are recorded in the list of Wenyon's *Protozoology* as the following :—

(*a*) *Hemidactylus leschenaulti* : *Trypanosoma leschenaulti* Robertson (1908) Ceylon ; *T. pertenue* Robertson (1908) Ceylon.



Trypanosomes of *Hemidactylus brooki* (1–6) ; 8·9 Rob. *Tryp. leschenaulti*. 13 Rob. *Tryp. pertenue* (after Robertson).

* According to the information kindly supplied by Dr. Baini Prashad the correct spelling of the species is *brooki*. In some of the former publications of the senior author the lizard has been pointed out as *brookei*. The necessary correction is therefore made here.

(*b*) *Hemidactylus triedrus* : *T. pertenue* Robertson (1908) Ceylon.

(*c*) *Hemidactylus gleadovii* : *Trypanosoma hemidactyli* Meckie, Gupta and Swaminath (1923) India.

The characters of *T. leschenaulti* are[1] : length of body 56–60, free flagellum 17–22. Rod-shaped kinetonucleus, well-developed membrane. Body extends a long way behind the kinetonucleus ; actively motile, often revolving in the figure of a wheel ; body very flexible. Many specimens much smaller.

Studying the figures 8, 9 of Miss Robertson we see that the rod-shaped kinetonucleus is situated at a certain distance from the anterior extremity and that the distance from this anterior point to the kinetonucleus is almost the same as that the distance between the kineto and the macronucleus.

The characters of *Trypanosoma pertenue* are : very delicate trypanosome ; length of body, 30–35 ; free flagellum, 15–30 ; small compact circular nucleus lying about half way from the non-flagellate tip. Kinetonucleus very minute, situated immediately behind the trophonuclear membrane. The author explaining the figure, notes, moreover the characteristic appearance of the nuclei, the absence of granules of any kind.

The study of *Trypanosoma hemidactyli* by the above-named Indian authors is incomplete and does not allow for the present a perfect identification. First of all there are doubts on the classification of their geckos, as the authors, stating that they were collected in Assam, seem to classify them as *H. gleadovii* and *H. coctœi*. We will quote their own words : " According to the *Fauna of British India* (*Reptilia and Batrachia*) quoted by Howlett[2] the commonest and most widely distributed species of geckos are *Hemidactylus gleadovii* and *H. coctœi* (*brokiisic* and *flaviviridis*). This being so, the geckos referred to in this paper are generically distinct from those (*Tarentola mauritanica*) from which the trypanosomes and herpetomonads have been described in Southern Europe and it is desirable at any rate provisionally to rename the flagellate found in the Indian species. They are therefore named *Trypanosoma hemidactyli* and *Herpetomonas hemidactyli* respectively, both new species.[3]

Or having asked information on the matter to the Zoological Survey of India, we verify that it is not possible to state with surety in what species this trypanosome was found ; they are " likely to be *H. brooki* Gray, *H. Karenorum* (Theob.) or some other species. In any case they cannot possibly be *H. flaviviridis* which according to the information published in Smith's latest revision of the genus in the *Fauna of British India* (*Lizard*), p. 98, does not occur east of Bengal.....Further *H. coctœi* is a synonym

of *H. flaviviridis* (private letter from Dr. Baini Prashad of the Zoological Survey of India, Calcutta)."

Secondly, the authors do not give any characters of their trypanosomes and their figures do not show distinctly the nuclear apparatus to enable us to take precise measurements which would be so useful for the identification of their trypanosomes. Anyhow the following numbers could be taken, after measuring with due scale their figures :—

Number	From the post. extr. to the base of the flagellum	From the post. extr. to the nucleus (?)	Free flagellum
1	13	5	10
2	18	6	9
3	17	?	8
4	14	?	9
5	18	?	7
6	18	?	10
7	20	?	6
8	18	?	6
9	21	?	14
10	22	?	7
11	17	?	9
12	19	?	6

In resumé ; length of body min. 13, max. 22 ; nucleus in 2 specimens at 5–6 from the post. extr.; free flagellum min. 6, max. 14.

Characters of the Trypanosome found by Us.

Many of these geckos have been examined by the senior author during years and it is the first time that trypanosomes have been found in specimens collected this year by one of us (L. L.) in the village of Socorro, Bardes.

General Morphology.—Somewhat flexible but not attaining the form of a wheel as described by Miss Robertson in *T. leschenaulti*. Posterior end pointed. Nuclear apparatus situated seldom in the middle but generally in

the posterior third. One peculiarity of this trypanosome is that the kinetonucleus appears under the form of a minute, very syderophyl grain, sometimes placed in a clear area (vacuole), and very close, almost attached to the posterior side of the nuclear membrane. In all the specimens such appearance does never fail. The macronucleus is ovoid and stains less strongly than the micronucleus. It has a granular endosome. The undulant membrane starts from the kinetonucleus, but the line of insertion is not perfectly accused. Its free border is limited by the axoneme which rarely takes a chromatic tinge, being in general deep blue at Romanowsky stain. In many specimens

Measurements (in microns).

From the post. extr. to the kinetonucleus	From the kineto to the macro	Diam. of the macro	From the macro to the ant. extr.	Free flagellum	Breadth
15	1	2	8	16	6
10	½	1	16	5	4
13	1	1	16	..	3
16	2	1	23	..	4
10	3	1	16	..	5
16	1	1	20	14	5
10	1	2	18	..	3
9	1	1	17	..	3
10	2	2	20	15	4
15	2	1	16	..	4
5	½	1	15	..	2
10	2	1	18	..	3
14	2	1	11	..	3
10	1	1	12	..	3
10	2	1	20	..	3
9	2	1	19	..	2
7	2	1	18	7	4
10	2	1	7	..	3
10	2	1	18	..	3
14	2	2	20	..	5
8	2	2	20	..	4
12	1	1½	18	..	3
10	2	1	15	..	3
13	1	1	25	..	3
9	1	2	14	..	2
3	1	1	10	..	2
12	2	1	11	5	4
11	1	2	10	..	4
9	1	1	17	..	3
16	1	1	19	10	3
11	1	2	16	8	3

one cannot notice the free flagellum which in others is distinctly visible. The cytoplasm of the trypanosome is devoid of granules, and does not show a uniform stain, some zones being coloured more deeply than others.

Some divisional stages have been found: (*a*) with one kinetonucleus and two macronuclei; (*b*) with two macro and micronuclei. It seems that the division begins by the macronucleus.

In resumé: from the posterior extremity to the kineto: min. 3, max. 16. From kineto to macro: 0·5 to 3. Diam. of the macro 1 to 2. From the macro to the anterior extremity: min. 7, max. 25. Free flagellum min. 5, max. 16.

Identification.—For the reasons exposed in this paper, we cannot compare our trypanosomes with *T. hemidactyli* of Mackie, Das and Swaminath. A study of their films should be necessary for collecting some data enabling to characterise their trypanosome.

Our species is not the *T. leschenaulti* of Miss Robertson.

It is, however, closely allied to *T. pertenue* Robertson. The total length of the body of our parasite is min. 15, max. 42.

Miss Robertson gives for her parasite 30–35 microns of length.

The free flagellum of our parasite min. 5, max. 16 and many of our trypanosomes do not show a free flagellum as it can be seen on the table.

We consider therefore our trypanosome a variety of *T. pertenue*, which will be named *Trypanosoma pertenue* var. *brooki* var. nov.

BIBLIOGRAPHY.

[1] Robertson Muriel, "A preliminary note on Hæmotozoa from some Ceylon reptiles," *Spolia Zylonica*, Dec. 1908, **5**, Part XX.

[2] *Ind. Jour. of Med. Res.*, July, 1913, **1**, No. 1.

[3] Mackie, F. P., Das Gupta, B. M., Swaminath, C. S., "Progress Report on Kala-azar," *Ind. Jour. Med. Res.*, 1923, **2**, No. 2, Foot-note.

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THE EFFECT OF CERTAIN EXTERNAL FACTORS UPON THE MANIFESTATION OF HYBRID VIGOUR IN WHEAT*

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1. Introduction

Though the scientific interest of hybrid vigour or heterosis is of long standing and much endeavour has been made to understand the real nature of the phenomenon this cannot yet be said to have been solved. In the present investigation attempt has been made to study the influence of certain external factors upon the outward manifestation of hybrid vigour in the hope that the results may throw some light on this recondite problem.

A review of the vast literature on hybrid vigour discloses that very few investigators have studied hybrid vigour from this angle. Mention must however be made of Bredemann and Heuser (1931), who were so impressed by the fluctuations of heterosis in rye from season to season that they recognised " good and bad heterosis years ", and Bolsunov (1936) who worked with tobacco (*Nicotiana rustica* L.). The latter author stated that soil drought sharply diminished heterosis, and other factors such as weather, rainfall, etc., also influenced its manifestation.

* Paper read before the session of the Indian Science Congress, held at Calcutta in January 1938.

Hybrid vigour in the crop used in the present investigation, *i.e.*, wheat, has been previously studied under normal conditions of cultivation by Engledow and Pal (1934), Griffee (1921) and Rosenquist (1931).

2. *Material and Method*

Two varieties of *Triticum vulgare* Host, *viz.*, Pusa 52 and Pusa 165, and the progenies of reciprocal crosses between them, were used in the present investigation. Pusa 52 is bearded while Pusa 165 is beardless; the F_1 is tipped and hence any selfed plants among the hybrids could be easily detected. The experiments which were carried out are described below:—

(i) *Experiment to investigate the influence of season and time of sowing on the manifestation of hybrid vigour*

Year	Material	Lay-out
1935–36	Pusa 52 Pusa 165 Pusa 52 × Pusa 165 Pusa 165 × Pusa 52	Randomised blocks with six replications, 50 seeds per plot. Sown on 29–10–35.
1936–37	Do.	Randomised blocks with six replications, 100 seeds per plot. Sown on 29–10–36, 12–11–36, 26–11–36, and 10–12–36.

The spacing was 12″ × 6″ in both the years.

(ii) *Experiment to investigate the influence of sowing at different depths on the manifestation of hybrid vigour*

Year	Material	Lay-out
1936–37	As for experiment (i)	(*a*) Randomised blocks with six replications, 30 seeds per plot. Sown on 30–10–36 at depths of 1″, 3″ and 5″. (*b*) Randomised blocks with six replications, 20 seeds per plot. Sown on 5–11–36 at depths of 1″, 2″, 3″, 4″, 5″ and 6″. (*c*) As (*b*) above, but sown on 10–11–36 and 11–11–36 at depths of 1″ and 2″, at 7 a.m. 12 noon, and 5 p.m. (*d*) As (*a*) above, but sown on 12–12–36.

The sowings were done with the sowing tube devised by Singh *et al* (1934).

(*iii*) *Experiment to investigate the influence of spacing on the manifestation of hybrid vigour*

YEAR	MATERIAL	LAY-OUT
1936–37	As for experiments (i) and (ii)	(*a*) Randomised blocks with six replications, 20–100 seeds per plot. Sown on 30–10–36 at plant-to-plant spacings of 3″, 9″ and 15″. (*b*) As (*a*) above, but sown on 12–12–36.

3. *Experiments and Results*

Hybrid vigour may be manifested in certain plant characters and not in others. In the present investigation comparison of the parent varieties and the reciprocal hybrids between them was made in respect of (1) germination, (2) rate of formation of first four foliage leaves and tiller, (3) plant height, (4) tillering, (5) number of leaves, (6) length of ear, (7) number of fertile and sterile spikelets, (8) number of grains per ear, (9) weight of grain and (10) yield, under different dates and times of sowing, different depths of sowing and different conditions of spacing. The results obtained are described in this section, each of the ten characters just mentioned being considered seriatum.

Germination

A. Total Germination

There were no significant differences in total germination between the parent varieties or the reciprocal hybrids when sowings were made at different spacings, at different times of the day or on different dates or when sowings were made at different depths up to three inches. Sowing at depths greater than three inches affected the total germination adversely. At depths of four, five and six inches the differences betweeen the F_1s and the parents were significant (at the one per cent. level in most cases and at the five per cent. level in the remaining cases, all the latter being in connection with the sowing at four inches depth). The germination percentages of the F_1 and the better parent at three different depths are given below :—

Sowing Depths

	1 inch	4 inches	6 inches
Better parent ..	100·0	86·4	72·4
F_1† ..	99·7	92·5	85·3

B. Rate of Germination

(i) *Effect of time of sowing on the rate of germination*‡—Seeds were sown at three times of the day, *viz.*, 7 a.m., 12 noon, and 5 p.m. In all cases, the germination percentage of the F_1 was initially better than that of the parents but the difference between them rapidly decreased. The initial difference was greatest in the case of the evening sowing and this least in the case of the morning sowing. The results are summarised below:

Percentage differences§ in germination between the parental average and the F_1 in sowings made at different times of the day

	1st Count	2nd Count	3rd Count
Morning sowing ..	6·7	4·4	1·8
Noon sowing ..	9·5	2·0	..
Evening sowing ..	14·5	2·8	..

(ii) *Effect of sowing at different depths on the rate of germination*—The rate of germination was obviously affected by sowing at different depths. The F_1 germinated earlier than the parent varieties and the differences between them were intensified with the increase in depth of sowing. The figures for sowings made at the normal sowing time are given below:

† The differences between the reciprocal F_1s were found to be insignificant throughout this investigation. For the sake of simplicity of presentation, the values of the reciprocals are not given separately in this paper.

‡ In 1935-36 daily counts of germination were made. In 1936-37 three-hourly counts were made.

§ In favour of F_1.

Percentage differences¶ in germination between the better parent and the F_1 in sowings made at different depths

	1st Count	2nd Count	3rd Count
1 inch depth ..	5·1	..	..
3 inch depth ..	8·4	23·3	1·6
5 inch depth ..	12·5	19·6	10·7

In the case of sowings made late in the season (December and January), the effect of sowing at different depths became still more conspicuous.

Rate of Formation of First Four Foliage Leaves, and Tiller

The rate at which the first green leaves and the first side-tiller become visible is a fairly well-defined characteristic. In 1935–36 there were daily counts of leaf formation while in 1936–37 the counts were made twice a day, *i.e.*, morning and evening. During the course of the study it was observed that there is a high positive association between the time taken for germination of seeds and formation of leaves. It is perhaps not surprising therefore that the rate of appearance of the first-formed foliage leaves is affected in a similar way by the factors influencing rate of germination.

First green foliage leaf—There is naturally a very high correlation between time of germination and the appearance of the first leaf, and the rate at which the first leaf appeared was almost the same as the rate at which the seeds germinated.

Second leaf—The percentage differences¶ between the values of the F_1 and of the better parent in the case of sowings at three different depths of sowing were :

	1st Count	2nd Count	3rd Count	4th Count
1 inch depth ..	18·5	10·0	7·3	..
3 inch depth ..	16·5	8·5	2·6	..
5 inch depth ..	14·0	20·5	8·4	2·7

¶ In favour of F_1.

When sowings were made at different times on the same day, the results were :

	1st Count	2nd Count
Morning sowing ..	+ 16·8	+ 1·1
Noon sowing ..	+ 11·0	− 0·2
Evening sowing ..	+ 9·9	− 2·9

In the case of sowings made on different dates of the same year the differences in favour of the F_1 were significantly greater in the later sowings. There was not much difference in the sowings made in the two years.

Third leaf—The range of time of appearance of the third leaf was much longer than that for the first and second leaves. The effect of season, time of sowing and depth of sowing was almost the same as that described for the second foliage leaf (*supra*).

Fourth leaf—The range of time of emergence of the fourth leaf was even wider than that for the third leaf. In both early and late sowings, at sowing depths of 1–3 inches, it was formed with or before the first side-tiller. But in late sowings at 5 inches depth it was always formed after the side-shoot had appeared. In early sowings this result of the depth of sowing was not observed. In late sowings the interval between the appearance of the fourth leaf on the main axis and the appearance of the side-shoot was significantly smaller for the F_1 as compared to the better parent. The effect of the other external factors was similar to that on the first three leaves.

First-side tiller—The results are shown in Fig. 1. The differences between the parents themselves were significant at only four out of the fourteen counts made. The differences between the F_1 and the better parent on the other hand were significant with the exception of the second and the last two counts.

At greater depths and in late sowings, the difference between the F_1 and its parents was still more pronounced. The effect of sowing at different times of the day however was not so obvious as in the case of rate of germination or appearance of the first four foliage leaves.

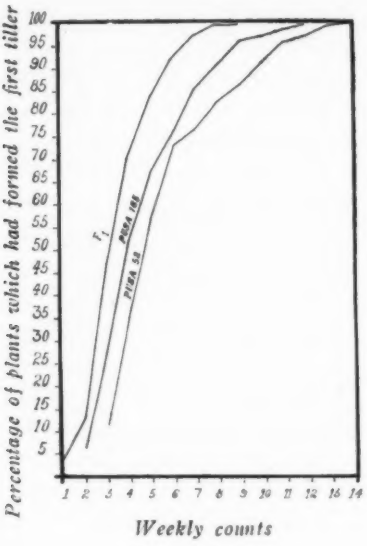

FIG. 1

Illustrating differences between the F_1 and the parents in rate of formation of the first tiller

Length of third leaf—In the case of one sowing the length of the third leaf was measured after all the third leaves had emerged. The results were :—

	Pusa 165	Pusa 52	F_1
Length of leaf (cm.) ..	4·04	2·70	4·60

The differences between the parents and between the better parent and the F_1 are statistically significant.

Height

In both the years measurements of the main stem were recorded weekly.

(i) *Effect of sowing on different dates and of season on the height of plant*—Four sowings were made in 1936, *viz.*, on 29th October, 12th November, 26th November, and 10th December. The results of weekly measurements are graphically represented in Fig. 2. The differences between the F_1 and the better parent after the commencement of "shooting" are significant except in the case of the last sowing which was made very late. When the plants were mature the height of the main stems and also of the tillers was measured. The results are rather striking and are given below :

Year	1935–36		1936–37							
Variety or hybrid	29th Oct. sowing		29th Oct. sowing		12th Nov. sowing		26th Nov. sowing		12th Dec. sowing	
	A	B	A	B	A	B	A	B	A	B
Pusa 52	100·5	92·6	91·8	83·6	88·0	73·5	88·5	74·0	76·0	61·5
Pusa 165	97·3	91·2	89·4	81·1	86·0	73·0	90·8	77·5	80·8	67·5
F_1	106·7	95·5	98·3	83·4	94·2	77·5	97·5	81·5	82·1	69·0
Percentage increase of F_1 over the better parent ..	6·2	3·1	7·1	..	7·0	5·4	7·4	4·9	1·6	2·2

A = Height of the main stem in cm.

B = Height of all the tillers (including the main stem) in cm.

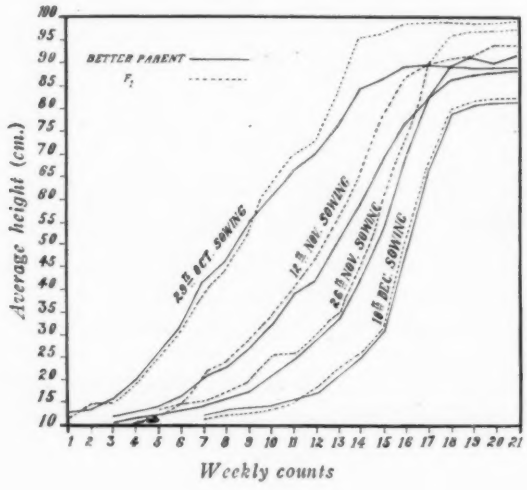

FIG. 2

Illustrating the comparative height of plant of the F_1 and the better parent when sowings were made on four different dates

The differences between F_1 and the better parent are significant in four out of five groups of sowings and indicate the presence of heterosis in respect of the character, height of main stem. It is evident from the figures given above, however, that if the height of all the tillers per plant is compared, the differences between the F_1 and the better parent are insignificant.

During the season 1935–36 the height of the plants in general was greater than in 1936–37, but the order of the differences between the F_1 and the better parent remained relatively the same.

(ii) *Effect of sowing at different depths and sowing at different spacings on the height of plant*—Neither of these factors appeared to have any consistent influence on the manifestation of hybrid vigour.

Tillering

Tillering, taken to mean number of side-shoots (including the main axis of the plant), was recorded weekly up to harvest. As tillering is a good criterion of vigour in wheat, the data in respect of this character are given in some detail in Table I.

It is evident from Table I that sowing on different dates has exercised a noticeable influence on the manifestation of hybrid vigour as estimated by the percentage difference between the number of tillers produced per plant by the parent varieties and their F_1 hybrid. The difference between the vigour of the F_1 and the parents is much clearer in the earlier than the later sowings.

The influence of season is comparatively unimportant, the figures for the two years being relatively similar.

Effect of other external factors—The data for sowings at different depths and spacings indicated that in the earlier counts differences between the F_1 and the parent varieties were more marked at the shallow and widely spaced plantings; in the later counts however, the differences became obscured.

Number of Leaves per Plant

The number of leaves per plant was counted weekly until they began to dry and shed. The number of leaves per plant in the early stages does not directly correspond with the number of tillers per plant when erect and prostrate varieties are compared. In erect varieties the tillers are taller and the number of leaves per tiller is therefore more than in the case of the prostrate varieties. Pusa 165 has an erect early habit whereas Pusa 52 has a procumbent early habit.

In the earlier stages the F_1 possessed a significantly larger number of leaves per plant than the higher parent, but the difference between them decreased with age and at the final counts the F_1 actually had a lesser number of leaves due to the fact that it ripened earlier and its leaves began to dry and fall before those of the parent variety. In fact at or near the ripening stage the number of leaves per plant is not an acceptable criterion of vigour.

TABLE I

Comparison of number of tillers per plant in the varieties Pusa 52 and Pusa 165 and the F_1 hybrid between them (1935–36 and 1936–37)

Variety or hybrid	Weekly Counts														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
							1935–36								
Pusa 52 ..	2·0	3·4	5·3	9·4	10·8	12·0	12·4	13·4	13·5	13·5	13·5	13·3	13·2		
Pusa 165 ..	2·7	3·9	6·0	7·7	8·9	10·7	11·1	11·7	12·0	12·3	12·2	12·4	12·3		
F_1	2·8	4·9	7·4	11·1	12·0	12·9	12·3	12·8	12·8	12·9	12·8	12·8	12·9		
A	3·7	33·3	23·3	18·1	11·1	10·7	− 0·1	− 4·5	− 5·2	− 4·4	− 5·2	− 3·8	− 2·3		
B	18·3	43·0	31·0	30·0	21·8	13·5	4·7	2·0	0·04	0·0	0·0	0·0	1·2		
First sowing—							1936–37								
Pusa 52 ..	1·0	2·1	3·7	6·4	7·8	9·4	11·0	11·9	13·4	13·8	14·1	13·9			
Pusa 165 ..	1·1	2·4	4·4	7·1	7·8	8·7	9·5	9·9	10·2	10·1	10·3	10·6			
F_1	1·3	3·5	5·3	7·7	8·7	9·8	10·3	10·9	11·8	12·0	12·4	12·3			
A	18·2	45·8	20·5	8·5	11·6	4·3	− 6·4	− 8·4	−11·9	−13·1	−12·1	−11·5			
B	23·8	51·1	30·8	14·1	11·6	8·3	0·5	0·0	0·0	0·4	1·6	0·4			
Second sowing—															
Pusa 52 ..	1·4	2·6	3·7	6·3	7·2	8·0	9·5	11·1	11·6	12·1	12·4	12·5	13·1	13·0	12·7
Pusa 165 ..	1·4	2·5	3·6	5·5	6·1	6·8	8·9	10·9	12·0	11·8	11·7	11·5	12·9	13·6	13·2
F_1	1·8	3·8	5·0	7·4	8·3	9·3	10·4	12·1	12·4	12·7	12·6	12·2	12·7	13·3	13·0
A	28·6	46·2	35·1	17·5	15·3	16·3	9·5	9·0	3·3	5·0	1·6	− 2·4	− 3·1	− 2·2	− 1·5
B	28·6	49·0	36·5	25·6	24·8	25·7	13·0	10·0	5·1	6·2	4·6	1·7	2·3	0·0	0·4
Third sowing—															

Third sowing—															
Pusa 52	..	2·8	4·0	5·7	8·1	10·9	11·7	13·0	12·9	13·9	14·7	14·4	14·4		
Pusa 165	..	2·6	3·7	5·7	8·5	9·7	10·7	11·6	12·1	12·1	13·5	14·4	13·7		
F_1	.. ..	3·1	4·6	6·7	8·8	11·1	11·4	12·4	13·4	13·7	14·4	14·9	14·2		
A	.. ..	10·7	15·0	17·5	3·5	1·9	−2·6	− 4·6	− 3·9	− 1·5	− 2·0	3·5	− 1·4		
B	.. ..	14·8	19·5	17·5	6·0	7·8	1·8	0·8	7·2	5·4	2·1	3·5	1·1		
Fourth sowing—															
Pusa 52	..	2·1	3·8	5·3	8·0	9·8	10·0	10·2	10·3	10·3					
Pusa 165	..	2·3	4·0	5·9	8·0	10·1	10·1	10·3	10·3	10·2					
F_1	.. ..	2·6	4·6	6·6	9·1	10·7	11·0	11·4	11·2	11·1					
A	.. ..	13·0	15·0	11·9	13·8	5·9	8·9	10·7	8·7	7·8					
B	.. ..	18·1	18·0	17·9	12·8	7·5	8·6	11·2	8·7	7·8					

A = Percentage increase or decrease of F_1 over better parent.
B = Percentage increase of F_1 over average of both parents.

The percentage increase in number of leaves per plant of the F_1 over the average of the parents is shown in Fig. 3. As Pusa 52 possessed more leaves at some counts and Pusa 165 at other counts, it was found convenient to compare the F_1 with the average of its parents rather than with only one of them.

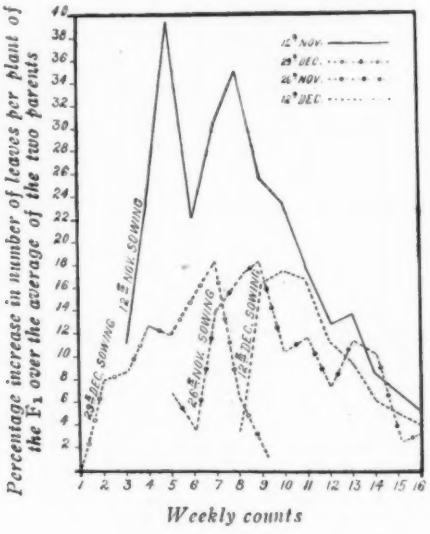
Percentage increase in number of leaves per plant of the F1 over the average of the two parents
Weekly counts
12th NOV.
29th DEC.
26th NOV.
14th DEC.
29th DEC. SOWING
12th NOV. SOWING
26th NOV. SOWING
14th DEC. SOWING

FIG. 3

Illustrating the increase in respect of number of leaves per plant of the F_1 over the average of the parents when sowings were made on four different dates.

Effect of sowing at different dates.—From Fig. 3 it is apparent that sowing at different dates has profoundly influenced the display of hybrid vigour in respect of number of leaves per plant. The sowing made on 12–11–36 was obviously the best date for the expression of heterosis in respect of the character under study.

Effect of season—The increase of F_1 over the average of the parents at the first three counts during 1935–36 was significantly greater than that for the corresponding counts in 1936–37. The differences at other counts were insignificant.

Other external factors.—The influence of depth of sowing and spacing was similar to that on number of tillers per plant (*vide supra*).

Length of Ear Etc.

The F_1s and the parents were compared in respect of the following ear characters :

Length of ear
Number of fertile and sterile spikelets
Number of grains per ear
Weight of grain

While in no cases were the differences between the F_1s and the better parent significant, the former (*i.e.*, F_1) in all cases exceeded the average of both the parents. The results as regards differential sowings are summarised in Table II.

TABLE II

Comparison of the F_1 hybrids between Pusa 52 and Pusa 165 with the average of the parents in respect of certain ear characters, under different dates ofsowing

Character studied	Percentage increase or decrease of the F_1 over the parental average				
	1935-36	1936-37			
		1st sowing	2nd sowing	3rd sowing	4th sowing
Length of ear (average of all the ears per plant) ..	+11·6	+ 5·9	+ 6·7	+ 7·8	+ 3·4
Do. (ears from main stems only) ..	+ 3·2	+ 7·3	+ 4·4	+ 8·0	+ 6·4
Number of fertile spikelets ..	+ 6·9	+ 6·7	+ 5·8	+ 7·6	+ 2·4
Number of sterile spikelets	− 2·2	− 7·6	− 6·0	−11·9	−15·5
Number of grains per ear (main stem ears only) ..	+ 2·1	+ 6·4	+ 2·8	+ 7·5	+ 9·8
Do. (all the ears) ..	+ 8·7	+10·3	+ 7·5	+ 6·8	+11·7
Grain weight ..	+16·6	+13·7	+12·4	−	−

The results in respect of differential spacing and depth of sowing are summarised in Table III.

TABLE III

Comparison of the F_1 hybrids between Pusa 52 and Pusa 165 with the average of the parents in respect of certain ear characters, under different spacings and depths of of sowing

Character studied	Percentage increase or decrease of the F_1 over the parental average					
	Plant-to-plant Spacing			Sowing Depth		
	3″	9″	15″	1½″	3″	5″
Length of ear ..	+ 5·0	+13·4	+11·0	+ 5·4	+ 6·7	+ 8·4
Number of fertile spikelets ..	+ 6·2	+ 8·4	+12·5	+ 7·8	+ 6·9	+ 8·4
Number of sterile spikelets ..	−10·2	− 7·8	− 5·4	− 6·4	− 4·2	− 4·8
Number of grains per ear ..	+ 9·8	+ 7·5	+ 7·1	+ 9·8	+ 8·7	+10·9
Weight of grain (late sowing) ..	+ 0·4	+ 0·8	+ 1·9	+ 1·4	+ 1·9	+ 0·8
Do. (early sowing) ..	+ 8·4	+ 9·5	+10·4	+ 9·5	+ 8·9	+10·4

Yield

Pusa 52 was significantly better in yield per plant than Pusa 165 in all the sowings except the very late December sowing. In the earlier sowings the F_1 was significantly better than the better parent, indicating that heterosis occurs in respect of yield.

The results are given below :—

Year	1936–37			
	1st sowing	2nd sowing	3rd sowing	4th sowing
	(yield per plant in grams)			
Pusa 52 ..	12·2	9·2	8·8	2·5
Pusa 165 ..	11·0	7·3	6·6	2·1
F_1 ..	13·8	10·1	9·1	2·5
Percentage increase or decrease over the better parent ..	13·1	9·7	4·0	2·4

4. Discussion

The data presented in this paper indicate that the expression of heterosis is greatly influenced by various external factors. Thus sowing at different dates considerably affected the degree of manifestation of heterosis in respect of all the characters studied (except the ear characters); this is perhaps due to the fact that sowings made at different dates within a season may provide more ecologically different conditions than where sowings are made from year to year at the normal sowing time. Most previous investigations on hybrid vigour have been carried out under one particular set of conditions only and it appears desirable in view of the results now presented to investigate hybrid vigour under as wide a range of conditions as possible in order to extend our knowledge of this phenomenon. In those crops, *e.g.*, tomato, egg-plant, where there is the possibility of commercial exploitation of hybrid vigour, it may be worthwhile to find out what are the optimum conditions for the expression of hybrid vigour in order to derive the maximum benefit from the use of F_1 seed.

5. Summary

1. Hybrid vigour was studied in a cross between two varieties of *Triticum vulgare, viz.*, Pusa 52 and Pusa 165, under different dates and times of sowing, different depths of sowing and different conditions of spacing. Although the cross did not show the striking effect that has made hybrid vigour notable in maize, it clearly displayed the phenomenon. There was no significant difference between the reciprocals under any of the treatments studied.

2. In total germination the F_1 was not superior to the parental varieties except when sowings were made at depths of 4–6 inches. Both time and depth of sowing however considerably affected the rate of germination. The increases (per cent.) of the F_1 over the better parent for morning, noon and evening sowings were 6·7, 9·5 and 14·5, and for 1-inch, 3-inch and 5-inch sowings, 5·1, 8·9 and 12·5 respectively. The differential response to sowing at different depths was still more conspicuous in the case of sowings made late in the season.

3. Manifestation of hybrid vigour in respect of the rate of formation of the first four foliage leaves and the first tiller was affected by all the external factors under study. The differences between the F_1 and the better parent (in favour of the former) varied from as much as 20·5 per cent. to nil.

4. Height counts (main stems only) showed that the differences between the F_1 and the better parent were significant in four out of five groups

of sowings and indicated the occurrence of heterosis in respect of this character. If however the height of all the tillers per plant was considered the differences were insignificant. Sowing at different depths and spacings did not produce any differential response in respect of this character.

5. The difference in tillering between the F_1 and the better parent was more striking in the earlier than in the later sowings, the percentage increase in favour of the F_1 varying from 46·2 to nil. There were some indications that sowing at different depths and spacing exercised an influence on this character, but the effect of season appeared to be relatively unimportant.

6. The influence of the external factors studied on number of leaves per plant was similar to that on tillering.

7. In respect of ear characters there were no significant differences between the F_1 and the better parent, although the former in all cases exceeded the average of both the parents.

8. In early sowings the F_1 was significantly better than the higher-yielding parent.

9. The data presented indicate that the expression of heterosis is greatly influenced by various external factors. The desirability of investigating hybrid vigour under as wide a range of conditions as possible is pointed out.

REFERENCES

Bredemann, G., and Heuser, W. — "Beiträge zur Heterosis bei Roggen," *Z. Züchtung A'*, 1931, **16**, 1–56.

Bolsunov, I. I. .. — "Studies on the heterosis or growth vigour in *Nicotiana rustica* plants" (Russ. with English summary), *U.S.S.R. Institute of Tobacco Investigations Bull.*, 1936, No. 132, 118–128.

Engledow, F. L., and Pal, B. P. — "Investigations on yield in cereals. VIII. Hybrid vigour in wheat," *J. Agric. Sci.*, 1934, **24**, 390–409.

Griffee, F. .. — "Comparative vigour of F_1 wheat crosses and their parents," *J. Agric. Res.*, 1921, **22**, 53–63.

Rosenquist, C. E. .. — "Hybrid vigour in wheat (*Triticum vulgare*)," *J. Amer. Soc. Agron.*, 1931, **23**, 81–105.

Singh, L., Ram, N., and Alam, N. — "A simple contrivance for sowing seeds at known depths," *Agric. and Live-Stock in India*, 1934, **4**, 268–269.

STUDIES ON THE STRUCTURE OF THE GOLGI APPARATUS.*

III. Some Observations on the Mechanism of Secretion of the Golgi Bodies in the Intestinal Cells of *Lumbriconereis*.

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Introduction.

In Part II of these "Studies" I showed that the relation between the secretion droplets and the Golgi apparatus in vertebrate cells was of four different types (Subramaniam, 1938). Further it was pointed out that the chromophobic component of the Golgi network in the liver cells of *Rhacophorus* becomes visible during the active production of bile components. As mentioned before, secretion in vertebrates and invertebrates appears to be similar and hence identical variation in the behaviour of the Golgi when found in relation with the secretory granules in invertebrate cells should also be noticed.

While working on the cytoplasmic inclusions of a gregarine parasitic in the gut of *Lumbriconereis* (Subramaniam and Ganapati, 1938) I accidentally came across some peculiar behaviour of the Golgi apparatus in the alimentary canal cells. These results confirm my conviction that there is *some fundamental plan in the Golgi apparatus common to all cells, whether vertebrate or invertebrate, and that the different patterns in different cells when analysed resolve into variations of a single basic procedure.*

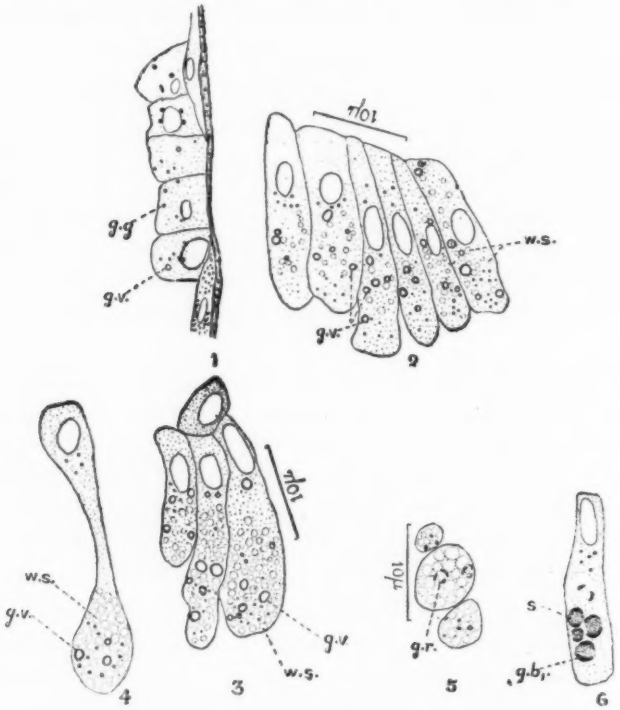
Observations.

The alimentary canal of *Lumbriconereis* contains two types of cells. There are vacuolated cells containing a watery mucous secretion in the region of the pharynx and at the hinder end of the alimentary canal. In the middle regions, the cells contain large granules which are fixed only by osmic acid technique. The secretion of both is by the Golgi apparatus as judged by their circumstantial relation to the secretory droplets. I shall describe here

* This Thesis along with Part II of these "Studies" was awarded the Maharaja of Travancore Curzon Prize by the University of Madras, in August 1937.

the behaviour of the Golgi apparatus during the secretory cycle based on Nassonov and Mann Kopsch material.

Cells with Watery Secretion.—In Fig. 1 is shown a group of cells during the beginning of secretory activity. The cells are small in size and the nucleus appears as a clear space. The Golgi bodies are found near the nucleus, some of them granular, a few being vesicular with chromophilic and chromophobic regions. The Golgi grains increase in number and a few of them enlarge into vesicles. They are scattered through the cytoplasm and secretion appears as clear vacuoles in close relation with these vesicles. It will be seen from Fig. 2 that as new droplets of secretion are formed, the older

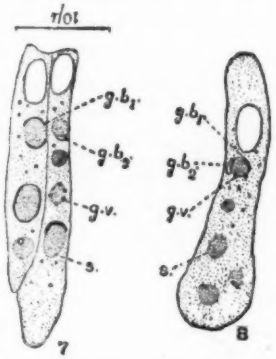


droplets are pushed away. The secretory vacuoles increase in number and appear scattered through the cytoplasm (Fig. 3). As secretion goes on the droplets begin to move towards the free end of the cell and in so doing carry most of the Golgi vesicles and granules to the lumen end of the cell (Fig. 4). The free end of the cell becomes bag-like and at the end of the secretory cycle, is cut off into the lumen of the alimentary canal. Such bits of cytoplasm

with secretion, together with degenerating Golgi bodies are seen in large numbers in the alimentary canal (Fig. 5).

Cells with Granular Secretion.—Secretion of granules seem to be different. Three different types of relation between the Golgi bodies and the secretory granules have been noticed. These granules in well-differentiated slides have a yellowish appearance and the Golgi bodies stand out as deep black structures. The early stages of spreading of the Golgi elements through the cytoplasm in these resemble the process in cells with watery secretion. But the Golgi vesicles may all remain as such or may enlarge and give rise to batonettes by rupture. Thus the resulting batonettes have the idiosome in relation with the cytoplasm. In some other examples, Golgi batonettes with the idiosome in relation with the cytoplasm, unmodified vesicles and double-rimmed batonettes were observed. These double-rimmed batonettes arise by a tucking in of the vesicles. As recorded by Subramaniam and Gopala Aiyar (1936 *a*) in *Lycastis* the double-rimmed batonettes in the alimentary canal cells have the chromophobic areas between the two rims.

The first type of relation between the Golgi bodies and the granules is shown in Fig. 6 (refer Figs. 2 and 3, Subramaniam and Gopala Aiyar, 1936 *b*). Here the granules arise in intimate relation with the chromophobic region of the Golgi batonettes. In the second type shown at *g.v.* in Fig. 7, small vesicles are seen closely pressed against the developing secretory granule.



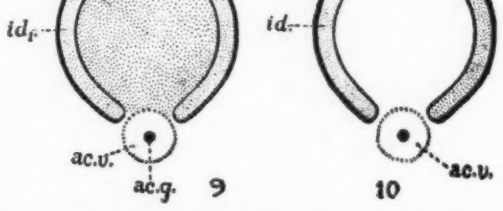
Thus secretory granules originate in relation with the chromophilic rims of the Golgi vesicles. In Fig. 8 is shown the third type of association. Typical batonettes, small Golgi vesicles and double-rimmed Golgi batonettes are seen plastered on the surface of the secretory granules. The excretion of these granules is also different. They escape into the lumen of the alimentary canal by the rupture of the cell. There is no storage of these granules before

extrusion and they are not sent into the alimentary canal all together. During extrusion some of them carry small pieces of the cytoplasm.

Discussion.

It will be seen that the diversity of origin of the secretory droplets in vertebrate cells has its counterpart in Fig. 8. As double-rimmed Golgi batonettes may be comparable to the network as regards the position of the idiosome, the question arises: is secretion by the double-rimmed batonette comparable to the secretion by the ordinary dictyosome? In this connection it is necessary to interpret the mechanism of working of the Golgi apparatus and my results on the intestinal cells of *Lumbriconereis* seem to offer a way out of the difficulty.

Bowen in 1920 described double-rimmed Golgi bodies in the spermatogenesis of a few insects. He has figured two appearances seen by him (his Text-Fig. 1, p. 329) after two different fixations. In the "modified Kopsch," the Golgi bodies gave one the impression of a pair of bent rods lying side by side enclosing in the cup-like area a substance which impregnates little or not at all. After the chrome-osmium methods, the peripheral rim alone is stained as a dark crescent on the side of the non-staining substance. The question arises, how are these appearances to be related and where exactly is the idiosome? Bowen described these bodies to be plate-like, but his figures definitely show that they are vesicular, as otherwise it is impossible to get in sections appearances of two concentric circles. Subramaniam and Gopala Aiyar (1936 *a*) showed that double-rimmed Golgi bodies occur in *Lycastis* and that the idiosome figured by Bowen between the two arms of the



U is only the faintly visible portion of the bodies when the double rims are in focus. This result has been confirmed, in the present investigation. According to the above interpretation, the appearances shown by Bowen after chrome-osmium fixatives turn out to be indistinct pictures resulting from the precipitation of osmic acid in the 'split' which is the real idiosome in the

batonette. In Fig. 9 is given Bowen's interpretation of acrosome formation and in Fig. 10 what it should be. It will be seen that in the latter figure there can be no idiosome between the two arms of the U and therefore the acrosome cannot be said to arise in close contact with the idiosome as in many other recorded instances. My results on the intestinal cells have confirmed the observations of Subramaniam and Gopala Aiyar that the double-rimmed Golgi batonettes originate from vesicles thus conclusively showing that the idiosome forms only a core to the double-rimmed batonettes. Double-rimmed batonettes have been noticed by several authors—as evidenced from their figures—though not actually described, but the method how it produces secretion is not understood properly.

This diversity in the structure of the Golgi apparatus in the attached condition (observed but not discussed by Subramaniam and Gopala Aiyar (1936 *b*) requires an interpretation. It will be seen that in mucous cells the bodies are vesicular and the secretion originates not inside the chromophobic part of the vesicle, but outside, in close relation with the chromophilic part. In the case of secretory granules, many of them originate in close connection with the chromophobic part of the Golgi batonettes. But the variations seen in the structure and shape of the Golgi bodies when found attached to the secretion granules throw some light on the mechanism of working of the Golgi apparatus. Judging from the uniform vesicular shape of Golgi in cells with watery secretion and the fact that in the majority, the secretory granules originate in the chromophobic area of the Golgi batonettes, it appears as if the shape of the apparatus is adapted to the nature of the secretion. Liquid form of secretion can thus diffuse out of a vesicle, whereas substances which are incapable of diffusing through a lipoid membrane arise near the chromophobic area. But the above correlation between the diffusibility of a substance and the shape of the Golgi apparatus is only apparent as vesicles and double-rimmed batonettes seen in relation with the granules have to be explained. It will be seen that in the case of acrosome formation (Bowen, 1922, 1926), the first product is the vesicle inside which a granule is differentiated (Fig. 9, *a.g.*). The reactions of the vesicle and granule are entirely different and the positional relationship is only between the Golgi body and the vesicle. In order to attribute the production of the granule to the Golgi batonette, we will have to conceive the vacuole as containing intra cellular enzymes secreted by the Golgi and the granule being the resulting product of the action of the enzymes on materials in the cytoplasm derived from various sources. Extending this interpretation (see also Subramaniam, 1937), the secretion of granules could be easily understood. As the liquid in a vesicle

with a diffusible membrane may escape through all the sides, it appears probable that the assumption of a batonette shape with double rims is an attempt at economy whereby most of the secreted enzymes collect in the cup-like area of the batonette. Thus in a batonette with the chromophobic region in relation with the cytoplasm, secretion droplets are formed in very close proximity to the idiosome itself, which along with the lipoidal part forms the centre of enzyme production in the cell. It will be seen that only such an enzyme secreting function of the Golgi apparatus can explain the secretion of the acrosome by the double-rimmed batonettes in some Pentatomids described by Bowen and in vertebrate gland cells where the Golgi networks have the chromophobic area as a core to the strands composing the network.

Summary and Conclusions.

Two kinds of secretion have been observed in the alimentary canal cells of *Lumbriconereis*. In cells producing a watery mucous secretion, the Golgi apparatus consists of granules and vesicles. The secretion vacuoles were observed to arise in contact with the chromophilic rim of the Golgi vesicles. As new droplets of secretion are formed the older droplets are pushed away from the Golgi elements. The secretion vacuoles collect near the lumen end of the cell which appears at this stage bag-like and is cut off into the alimentary canal lumen.

In cells producing the granular type of secretion three types of association between the Golgi bodies and the secretory product were observed. (1) Granules were seen arising in intimate relation with the idiosome of the Golgi batonettes. (2) Developing granules were seen to be closely pressed against small Golgi vesicles. (3) Typical Golgi batonettes, double-rimmed batonettes and Golgi vesicles were seen plastered on the surface of a secretory granule.

A theory regarding the mechanism of working of the Golgi apparatus is given, which would bring into line the secretion of various substances by the Golgi apparatus in invertebrates with that in vertebrates.

Acknowledgments.

My thanks are due to Professor R. Gopala Aiyar for his criticisms and encouragement and to the University of Madras for awarding me a Research Fellowship.

BIBLIOGRAPHY.

Bowen, R. H. .. "Studies on Insect Spermatogenesis. I. History of the Cytoplasmic Components of the Sperm in Hemiptera," *Biol. Bull.*, 1920, **39**, 316–359.

———— .. "On the Idiosome, Golgi Apparatus and Acrosome in the Male Germ Cells," *Anat. Rec.*, 1922, **24**, 159–180.

———— .. "Studies on the Structure of the Golgi Apparatus in Gland Cells. IV. A Critique of the Topography, Structure and Function of the Golgi Apparatus in Glandular Tissue," *Quart. Journ. Micr. Sci.*, 1926, **70**, 419–451.

Subramaniam, M. K. .. "Oogenesis of *Meretrix casta* (Chemnitz) with a Note on the Nature of the Contents of Neutral Red Vacuoles," *J. Morph.*, 1937, **61**, 127–148.

———— .. "Studies on the Structure of the Golgi Apparatus. II. Liver Cells of *Rhacophorus maculatus* Gray," *Proc. Ind. Acad. Sci.*, 1938, **7**(B), 80.

Subramaniam, M. K., and Ganapati, P. N. "Studies on the Structure of the Golgi Apparatus. I. Cytoplasmic Inclusions of the gregarine *Lecudina brasili* (n.sp.) parasitic in the gut of *Lumbriconereis*," *Cytologia* (In press), 1938.

Subramaniam, M. K., and Gopala Aiyar, R. "Some Observations on the Possible Mode of Evolution of the Networklike Golgi Apparatus of Vertebrate Somatic Cells from Discrete Golgi Bodies of Invertebrates," *La Cellule*, 1936 *a*, **45**, 61–73.

———— .. "Secretion of Fatty and Albuminous Yolk by Golgi Bodies in *Stomopneustes variolaris* Lamarck," *Zeit. zellf. u. mikr. Anat.*, 1936 *b*, **24**, 576–584.

KEY TO LETTERING.

ac.g., Acrosomal granule; *ac.v.*, Acrosomal vesicle; $g.b_1$., Golgi batonette with the chromophobic area in relation with the cytoplasm; $g.b_2$., Golgi batonette with the chromophobic area between the two chromophilic rims of the batonette; *g.g.*, Golgi granule; *g.r.*, Degenerating Golgi; *g.v.*, Golgi vesicle; *id.*, Idiosome; id_1., Idiosome between the two chromophilic rims of batonette; id_2., Idiosome supposed to be present in the cup-like area of the batonette; *s.*, Secretory granule; *w.s.*, Vauoles of watery secretion.

EXPLANATION OF FIGURES.

Fig. 1.—Alimentary Canal cells just before they begin to secrete.

Fig. 2.—Beginning of secretion. Watery droplets make their appearance in relation with the Golgi apparatus.

Fig. 3.—Cells at the height of secretory activity.

Fig. 4.—Secretion droplets collecting near the free end of the cell.

Fig. 5.—Cut off portions of cells containing secretory droplets and degenerating Golgi bodies lying free in the alimentary canal lumen.

Fig. 6.—Secretory granules originating in relation with the chromophobic area of Golgi batonettes.

Figs. 7 & 8.—Golgi vesicles, double-rimmed batonettes and ordinary batonettes in relation with secretory granules.

Fig. 9.—Bowen's conception of Acrosome formation in *Euschistus*.

Fig. 10.—Modified view in the light of work on *Lycastis* and *Lumbriconereis*.

STUDIES ON THE TREMATODE PARASITES OF FISHES. A NEW TREMATODE *NEOGANADA BARABANKIAE* (NOV. GEN., NOV. SPEC.) FROM *CLARIAS BATRACHUS*.

By J. Dayal, M.Sc.

(*From the Department of Zoology, University of Lucknow, Lucknow.*)

Received January 24, 1938.

(Communicated by Dr. G. S. Thapar, M.Sc., Ph.D.)

Lühe (1909) described *Leptophallus nigrovenosus* from the œsophagus of *Tropidonotus natrix*. Chatterji (1933) described *Ganada clariæ*, a form closely related to *Leptophallus*, from the intestine of *Clarias batrachus*. The form described in the present communication is related to *Leptophallus* and *Ganada* but differs from both the genera in several important characters which necessitate the erection of a new genus for its reception.

Neoganada barabankiæ (Nov. gen., Nov. spec.).

Neoganada barabankiæ is a small elliptical trematode with rounded anterior and posterior ends. It is 1·63 mm. long by ·37 mm. broad in the region of the öotype. The skin is covered with minute backwardly directed spines.

The oral sucker is circular, sub-terminal and ·17 mm. in diameter. The ventral sucker is smaller than the oral sucker and is ·14 mm. in diameter. It is situated at a distance of ·58 mm. from the anterior end.

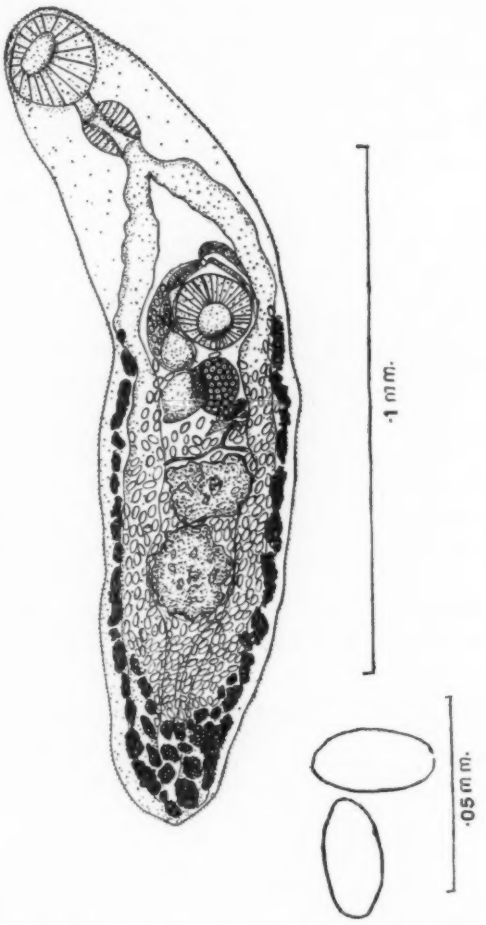
The mouth is a small oval opening in the anterior region of the ventral sucker. It leads into a small prepharynx ·04 mm. long by ·03 mm. wide, followed by a strong muscular pharynx ·08 mm. long by ·09 mm. broad. Posterior to the pharynx is a short œsophagus ·05 mm. long by ·04 mm. broad. The latter bifurcates into two simple intestinal cæca which run upto the posterior end of the body.

The excretory bladder begins at the excretory pore situated at the posterior end, and leads into a long tube extending as far as the posterior testis where it divides into two short branches one lying on either side of the testis.

The genital opening lies in front of the ventral sucker in the median line.

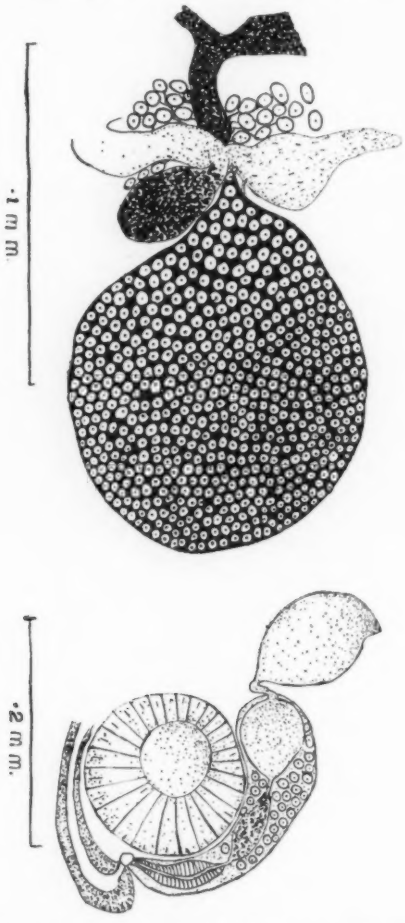
The male reproductive organs consist of two slightly lobed testes situated one behind the other in the posterior half of the body. The anterior testis

is situated at a distance of ·92 mm. from the anterior end, and is ·11 mm. long by ·15 mm. broad. The posterior testis is larger than the anterior and is ·18 mm. long by ·15 mm. broad. It is at a distance of 1·05 mm. from the anterior end.



The cirrus sac is a crescent-shaped organ lying on the right side of the ventral sucker and embracing it. It is narrow in front and broader posteriorly and is ·26 mm. long by ·07 mm. broad in the region of the vesicula seminalis. The organs contained in the cirrus sac are the vesicula seminalis interna, parsprostatica, ductus ejaculatorius and a retracted cirrus. The seminal vesicle consists of two parts, (1) a vesicula seminalis interna, an oval

organ contained within the cirrus sac, and (2) a vesicula seminalis externa, a large sac-like portion lying freely in the parenchyma and extending from the cirrus sac to the hinder region of the ovary. The vesicula seminalis interna is oval in shape and is ·07 mm. long by ·055 mm. broad. The



vesicula seminalis externa is larger than the internal portion of the vesicula seminalis. It extends to the posterior end of the ovary, and is ·12 mm. long by ·08 mm. broad. The vesicula seminalis interna opens through a short duct into a parsprostatica, about ·065 mm. long by ·025 mm. broad. This leads through a short narrow ejaculatory duct into a retracted and an elongated muscular cirrus, ·08 mm. long. The latter organ opens at the

genital pore in front of the ventral sucker. A large number of unicellular prostate gland cells open into the parsprostatica and fill up the entire space in the cirrus sac round the vesicula seminalis and the parsprostatica.

The female organs consist of an ovary and its duct together with a number of accessory organs associated with it. The ovary is an oval organ lying at a distance of ·74 mm. from the anterior end and ·07 mm. in front of the anterior testis. It is ·11 mm. long by ·09 mm. broad. From its posterior end arises the oviduct which opens at the öotype. A pear-shaped receptaculum seminis lies on the right side behind the ovary and opens at the öotype. It is ·052 mm. long by ·022 mm. broad and is connected with a small Laurer's canal which opens to the outside.

The vitelline glands are very extensive, and lie on the lateral sides extending from the ventral sucker to the posterior region of the body where they extend to the middle region. The two transverse vitelline ducts formed by the union of other ducts run in front of the anterior testis and join to form a common duct. The latter runs forwards to open at the öotype. A pear-shaped yolk-sac lies on the left side near the opening of the yolk duct. It is ·034 mm. long by ·02 mm. broad.

A large number of oval unicellular shell glands each with a large nucleus surround the öotype and open into it.

The uterus arises from the left side of the öotype. It then coils transversely and runs to the posterior end of the body to return through the same course. Owing to the large number of eggs it is difficult to follow the descending and ascending coils of the uterus. Anteriorly it forms a muscular metraterm and runs on the left side of the ventral sucker to open at the genital pore.

The eggs are oval in shape with a thin light brown shell. They mesaure ·030–·031 mm. in length by ·014 mm.–·016 mm. in breadth.

The distinguishing characters of the new form may be summarised as follows :—

1. Oral sucker larger than ventral sucker.
2. Testes tandem slightly lobed and situated in the posterior half of the body.
3. Cirrus sac crescentic on the right side of the ventral sucker.
4. Vesicula seminalis interna and externa large in size.
5. Receptaculum seminis and Laurer's canal present.
6. Vitelline glands from the ventral sucker to the posterior end where they extend to the middle region.
7. Yolk-sac present.

8. Uterus with transverse coils. A muscular metraterm on the left side of the ventral sucker.
9. Eggs : ·030–·031 mm. long by ·014–·016 mm. broad.

Discussion.

Neoganada, as will appear from the description, belongs to the family *Plagiorchiidæ* but differs from all the members of the family except *Leptophallus* and *Ganada*, in having the vesicula seminalis divided into two parts (1) vesicula seminalis interna lying within the cirrus sac and (2) vesicula seminalis externa lying outside the cirrus sac freely in the parenchyma. *Neoganada* differs from *Ganada* in the relative size of suckers, in having lobed testes, in the presence of receptaculum seminis and yolk-sac, in the arrangement of uterine coils and in the presence of a muscular metraterm. *Neoganada* differs from *Leptophallus* in the extent of intestinal cæca, in having lobed testes one behind the other, in the structure and relative position of cirrus sac, in the distribution of vitelline glands, in the arrangement of uterine coils and in the presence of a muscular metraterm. These differences along with the relative size and the general topography of organs are enough to establish a new genus, which may be defined as follows :—

Plagiorchiidæ, body elongated, cuticle with spines, oral sucker larger than the ventral sucker, prepharynx, pharynx and a small œsophagus are present. Intestinal cæca simple and extend to the posterior end of the body. Genital opening is median and immediately in front of the ventral sucker. Testes slightly lobed and one behind the other. Cirrus sac large, crescentic in shape and on the right side of the ventral sucker. Vesicula seminalis consists of two parts interna and externa, parsprostatica, prostate glands and a retracted muscular cirrus present. Ovary entire, oval in shape and in front of the testes. Receptaculum seminis and Laurer's canal are present. Vitellaria with closely packed follicles extending laterally from the ventral sucker to the posterior end ; yolk sac present. Uterus with transverse coils and a large number of eggs extending to the posterior end of the body. Metraterm muscular, on the left side of the ventral sucker. Eggs oval in shape and with thin light brown shell. Excretory bladder Y-shaped with short diverticula.

Type species.—*Neoganada barabankiæ*.
Host.—*Clarias batrachus*.
Habitat.—Intestine.
Locality.—Barabanki.

I am deeply indebted to Dr. G. S. Thapar for his kind help and placing at my disposal his valuable library.

Type species deposited in Dr. Thapar's Helminthological collections, Lucknow University.

REFERENCES.

1. Baer, J. G. .. "Description of a new genus of *Lepodermatidæ* (Trematoda) with systematic essay on the family," *Parasit.*, 1924, **16**.

2. Chatterji, R. C. .. "On the trematode parasites of a Rangoon Siluroid fish, *Clarias batrachus* (Linnaeus, 1785)," *Bull. Acad. Sci., Allahabad*, 1933, **3**.

3. Fuhrmann, O. .. "Trematoda," in Kukenthal's *Handbuch der Zoologie*, 1928, Band 2. (Berlin und Leipzig.)

4. Lühe, M. .. "Parasitische Plattwürmer 1 'Trematodes'," in *Die Süsswasserfauna Deutschlands*, 1909, Heft 17.

A NEW TREMATODE, *PHYLLOCHORUS MACRONIUS*, N. GEN., N. SP. BELONGING TO THE FAMILY *GORGODERIDAE* LOOSS (1901), FROM THE BODY-CAVITY OF A FRESH WATER FISH, *MACRONES TENGARA*.

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(From the Department of Zoology, University of Lucknow, Lucknow.)

Received February 23, 1938.

(Communicated by Dr. G. S. Thapar, M.Sc., Ph.D.)

The trematodes were collected from the body-cavity of a fresh-water fish *Macrones tengara*. They belong to the family *Gorgoderidæ*, but as they differ from all the known genera in important characters a new genus is erected for their reception.

Phyllochorus macronius, N.G., N.Sp.

The new form, *Phyllochorus macronius*, is a much flattened trematode of white colour with smooth skin devoid of spines. The anterior portion of the body is narrow and elongated while the posterior portion of the body is much expanded and nearly circular. The worm is 3·15 mm. long by 1·85 mm. broad. The narrow anterior part is 1·25 mm. long by ·55 mm. broad and the posterior expanded portion is 1·9 mm. long by 1·85 mm. broad.

The oral sucker is circular and subterminal in position. It is ·4 mm. in diameter. The ventral sucker is oval in shape and smaller than the oral sucker. It is ·35 mm. long by ·34 mm. broad and is situated at the junction of the neck and the broad portion of the body at a distance of 1·2 mm. from the anterior end.

The mouth is a small oval opening in the anterior region of the oral sucker and is subterminal in position. It leads into a long œsophagus ·41 mm. long by ·09 mm. broad. The latter bifurcates into two simple intestinal cæca which run up to the posterior end of the body.

The excretory bladder begins at the excretory pore situated at the posterior end of the body on the ventral side, and leads into a long tube extending as far as the testes.

The genital opening is situated behind the intestinal bifurcation at a distance of ·9 mm. from the anterior end and ·3 mm. in front of the ventral sucker.

The male reproductive organs consist of two testes, connubial in position and situated in the anterior half of the broad portion of the body lying

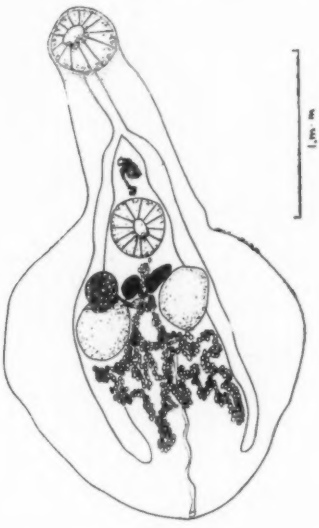

FIG. 1.

partly on the ventral side of the intestinal cæca. The right testis is larger than the left and is ·4 mm. long by ·31 mm. broad. It is situated at a distance of 1·8 mm. from the anterior end. The left testis is ·39 mm. long by ·30 mm. broad. It is situated at a distance of 1·7 mm. from the anterior end slightly anterior to the right testis.

The cirrus sac is absent. The vesicula seminalis lies freely in the parenchyma and is oval in shape. It is ·08 mm. long by ·065 mm. broad. It opens into an S-shaped ejaculatory duct which opens at the genital pore. A large number of unicellular prostate gland cells surround the ejaculatory duct.

The female genital organs consist of an ovary and its duct together with a number of accessory organs associated with it. The ovary is situated in front of the right testis partly covering it and the intestinal cæcum on the ventral side. It lies at a distance of 1·57 mm. from the anterior end and nearly at the same level as the vitelline glands. It is oval in shape and is

·23 mm. long by ·22 mm. broad. From its left side arises the oviduct which opens at the öotype. A large pear-shaped receptaculum seminis lies on the right side of the öotype, ventral to the oviduct. It is ·1 mm. long by ·06 mm.

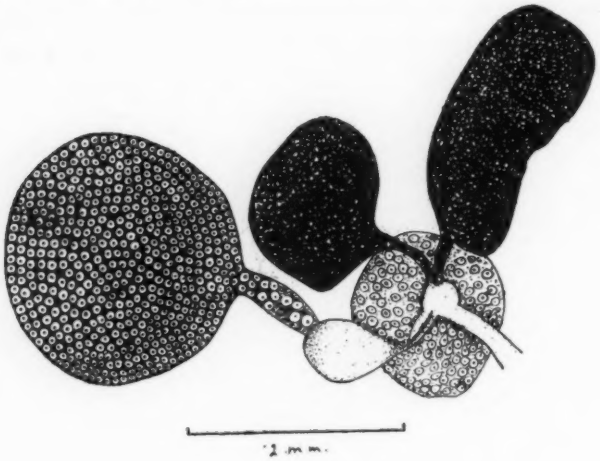

Fig. 2.

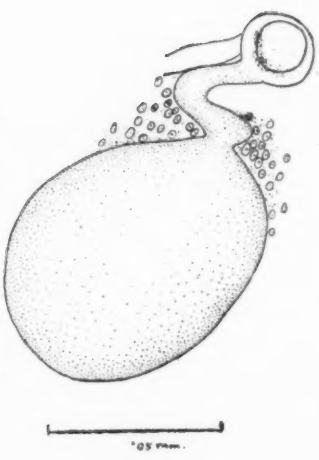

Fig. 3.

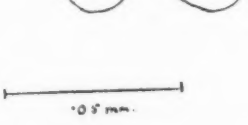

Fig. 4.

broad. The vitelline glands consist of two large undivided follicles situated in the middle on the antero-lateral sides of the öotype behind the ventral sucker, at a distance of 1·6 mm. from the anterior end. The right vitelline

gland is more or less oval in shape and is ·16 mm. long by ·12 mm. broad. The left vitelline gland is cylindrical in shape and is larger than the right gland. It is ·23 mm. long by ·11 mm. broad. The ducts from the two glands open separately at the öotype. A large number of unicellular shell glands each with a large nucleus surround the öotype.

The uterus arises from the posterior side of the öotype opposite the opening of the right vitelline duct and runs backwards forming coils between the intestinal cæca posterior to the testes. Anteriorly it runs dorsal to ventral sucker to open at the genital pore.

The eggs are oval in shape with an operculated thick brown shell. They measure ·029–·031 mm. in length by ·021–·023 mm. in breadth.

Discussion.

The new form *Phyllochorus macronius*, as will appear from the foregoing description belongs to the family *Gorgoderidæ*, but differs from the genera *Gorgodera*, *Gorgoderina*, *Phyllodistomum*, *Macia* and *Xystretum* chiefly in the presence of receptaculum seminis, a character of generic importance. And it differs from *Anaporrhutum*, *Plesiochorus*, *Probolitrema*, *Petalodistomum*, *Staphylorchis* and *Nagmia* in the relative position and shape of testes, ovary, vitelline glands and the structure of the excretory bladder. These differences along with the general topography of organs are enough to erect a new genus with the following definition:

Gorgoderidæ with flat body divided into an anterior narrow elongated portion and a posterior expanded nearly circular part. Pharynx absent, œsophagus long. Intestinal cæca simple and extending to the posterior end of the body. Genital pore between the intestinal bifurcation and the ventral sucker. Testes rounded lying partly on the ventral side of the intestinal cæca. Ovary rounded and lying at the same level as the vitelline glands on the ventral side of the intestinal cæcum. Vitelline glands two and unbranched situated on the antero-lateral sides of the öotype. A receptaculum seminis is present. Uterus intercæcal. Excretory bladder tube-shaped. Eggs operculated with thick brown shell.

(In the body-cavity of fresh-water fishes.)

Type Species.—Phyllochorus macronius deposited in Dr. Thapar's Helminthological Collection, Lucknow University.

I am indebted to Dr. G. S. Thapar for his kind help and placing at my disposal his valuable library.

REFERENCES.

1. Bhalerao, G. D. .. "Studies on the helminths of India, Trematoda IV," *Jour. Helminth.*, 1937, **15**.
2. Fuhrmann, O. .. "Zweite klasse des cladus Plathelminthes, Trematoda," W. Kukenthal's *Handbuch der Zoologie*, Berlin und Leipzig, 1928.
3. Holl, F. J. .. "New trematodes of the newt *Triturus viridescens*," *Jour. Helminth.*, 1928, **6**.
4. Johnston, S. J. .. "On some Queensland trematodes, with anatomical observations and descriptions of new species and genera," *Quar. Jour. Mic. Sci.*, 1913, **59**.
5. Linton, E. .. "Helminth fauna of Dry Tortugas, 2. Trematodes," *Papers of the Tortugas lab. Carnegie Inst., Washington*, 1910, **4**.
6. Loewen, S. L. .. "A description of the trematode *Catoptroides lacustri*, n.sp., with a review of the known species of the genus," *Parasitol.*, 1929, **27**.
7. Lewis, F. J. .. "Trematodes of the genus *Phyllodistomum*, Braun," *Trans. Amer. Mic. Soc.*, 1935, **54**.
8. Nagaty, H. F. .. "A new *Anaporrhutine* trematode genus and species, *Nagmia yorkei*, with a review of the classification of the sub-family," *Annal. Trop. Med. and Parasit.*, 1930, **24**.
9. Ozaki, Y. .. "On two new genera of frog trematodes, *Cryptotrema* and *Microlecithus*, and a new species of *Pleurogenes*," *J. Fac. Sci., Tokyo*, 1926, Sec. IV, Zool. 1.
10. Olsen, O. W. .. "A new species of bladder fluke, *Gorgoderina tanneri* (*Gorgoderidæ*, Trematode), from *Rana pretiosa*," *Jour. Parasitol.*, 1937, **23**.
11. Rankin, J. S. (Jr.) .. "New helminths from North Carolina Salamander," *Jour. Parasitol.*, 1937, **23**.
12. Stunkard, H. W. .. "A new trematode, *Probolitrema californiense*, from the cœlom of Sting Ray, *Myliobatus californicus*," *Jour. Helminth.*, 1935, **21**.
13. Travassos, L. .. "Contribuicoes para O conhecimento da fauna helmintologica brasileira, XIV. Especies brasileiras da familia *Gorgoderidæ* Looss (1901)," *Bras. Med. Ann.*, 1920, **36**.
14. ———— .. "Contribuicoespara O conhecimento da fauna helmintologica brasileira, XVII. *Gorgoderidæ bresilienses*," *Mem. Do. Inst. Oswal. Cruz.*, 1922, **15**.
15. ———— .. "Fauna helminthologica de Matto Grosso," *Mem. Do. Inst. Oswal. Cruz.*, 1928, **21**.
16. Yamaguti, S. .. "Studies on the helminth fauna of Japan, Part 2, Trematodes of fishes," *Jap. Jour. Zool.*, 1934, **15**.

THE LIGHT FACTOR IN CROP PRODUCTION

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Introduction

Of the many conditioning variables that seem to regulate the growth and development of plants, the one which is by far the most closely linked to the basic phenomena of assimilation and growth, is light. The nature of plant response to variations in the intensity or duration of this factor, however, remained unelucidated until recently when the directive action of light in tropistic and kindred phenomena, its influence in the determination of growth forms and facies of the flora, as also its regulatory action upon the assimilatory process were investigated in their fuller details. Analysing the response of *Sempervivum* to seasonal variations, Klebs[17] showed that the crop normally flowering in June could be forced to flower in winter, if the illumination period be increased to more than twelve hours. Turesson[29] observed that the plagiotropic horizontal shoots of the prostrate maritimal form of *Atriplex* grew upright in reduced light and concluded that such an adjustment is of great importance in plant society where the inhabitants have a struggle for space. Continuous investigation by Garner and Allard[10–13] showed that flowering and fruiting stages of plants fall within certain limits and that in the absence of particular length of the day favourable to sexual reproduction, vegetative development may continue for a more or less indefinite period, thus frequently leading to the phenomenon of gigantism.

Our knowledge of the specific relationship between the light factor and growth, however, is mostly due to the investigations of Garner and his associates,[10–14] McClelland,[18] Eaton,[9] Nightingale,[19] Adams,[1–6] Deats[8] and Tincker[25–28] among others. In almost all these works the complexity of the growth mechanism and the lack of a proper realisation of the plants' reaction to a given constellation of ecological factors have been the serious handicaps, for, the majority of the previous investigations have been conducted in disregard of factors other than illumination. The covering of plants with bell-jars for varying the intensity and duration of light (*cf.* Adams) although useful in certain respects, did not take into consideration the effect of partial

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etiolation, the maintenance of a proper supply of oxygen and carbon dioxide, as well as the humidity state in the atmosphere. Furthermore, the increase in height or variation in weight of a few tall plants, so often adopted by workers in this field as criteria of growth measurements did not seem to give a significant estimate of the responsiveness of plants specially under experimentation where the influence of light was to be studied.

Our outlook in carrying out this investigation, thus, had been three-fold:

(i) To make a precise determination (qualitative and quantitative) of the growth behaviour of certain crop plants in relation to light conditions of the environment with due regard to other factors;

(ii) To compute as far as possible the specific light requirement* of the experimental plants ensuring the maximum possibilities of growth and yield ; and

(iii) To analyse the extent of response of plants to light conditions in relation to their differences in constitution and season of growth.

The accumulation of dry matter was adopted in this work as one of the satisfactory measures of growth determination in plants. This method evidently had the advantage that any deviation from the expected could be confirmed from an independent evidence at the next measurement. No such confirmation was, however, possible on using the same material again and again. Special attention was also directed to the control and maintenance of environmental factors under as nearly uniform conditions as practicable.

Experimental

Pure strains of *Triticum vulgare* (*var.* Pusa 4), *Hordeum vulgare* (*var.* 255), *Linum usitatissimum* (*var.* 1150 S), *Brassica campestris* (*var.* selected yellow), *Crotalaria juncea* (*var.* local) and *Gossypium herbaceum* (*var.* Cawnpore 402) were grown in pots under limited light-darkness† conditions. Factors other than illumination which directly or indirectly limit growth were kept well above their limiting values. Soil pH was maintained at 6·5 and the saturation limit at 22 ± 1 per cent. From the ceiling were suspended, ten 1,500-watt Phillip lamps fitted in polished parabolic reflectors distributing uniform light to the experimental plants. The distance between the lamps and the plants was kept constant by raising the former as the latter grew, such that the intensity of light in the vicinity of plants when measured photoelectrically remained 80,000 m.c.—an intensity which was found to

* The amount of light essential to produce unit dry matter or grain yield at varying diurnal durations of nonlimiting intensity.

† The shorter durations indicate limited light and longer limited darkness.

be above the limiting value for photosynthesis.[23] The plants were protected from excess of radiant heat by interposing a screen of running water. Thermographic records were regularly maintained and the mean temperature of the irradiation laboratory was kept at 29 ± 1·5° C. by the circulation of fresh air at a constant velocity of 250 metres per minute. The concentration of CO_2 fluctuated from 0·035 — 0·050 per cent. while the relative humidity as recorded by a hygrograph was held constant within about ± 2 per cent. The soil temperature ranged between 32° and 33·5° C. Such a range of factor intensity was maintained throughout the entire life-cycle of crops under observation. Ten series of experiments were conducted with varying durations of light ranging between zero hours and continuous illumination. Morphological differences and other characteristic features were regularly noted. For dry matter determinations, 25 plants and more were washed free of all contaminations at successive stages from each of the series and incubated at 105° C. to a constant weight. A full account of the observational technique employed herein was detailed in a previous publication[22] from this Experiment Station, to which the reader is referred. The data collected were tested statistically for the isolation of relevant results and analysed with special reference to crop production relative to the duration of light supply.

Experimental Findings

The experimental series of plants are exposed to varying durations of illumination and the nature of their response is studied throughout the life-cycle. The light exposures given to the plants are broadly divisible into *short* and *long*, as detailed *ut infra* :

Short Durations‡ :

1. Eight hours per diem,
2. Six ,, ,, ,,
3. Four ,, ,, ,,
4. Two ,, ,, ,,
5. One ,, ,, ,, and
6. Zero illumination.

Long Durations :

1. Fifteen hours exposure per day,
2. Eighteen hours exposure per day, and
3. Full twenty-four hours illumination
   (with no period of dark conditions).

‡ In view of explaining the results according to the degree of departure from the normal conditions of light, short durations are purposely arranged in a reverse order.

Besides the above nine sets of plants grown under short or long durations, those that are raised under twelve hours daily illumination but otherwise identical conditions are taken as control (normal), since in this particular case the duration of exposure approaches very nearly to the period to which ordinary plants in the open are exposed to sunshine in this region.

Short-duration Experiments—The development of chlorophyll in the seedlings as well as in the young plants varies in direct proportion to the duration of illumination as is indicated by tests made after using Oltman's spectrophotometric method[20] (Table I). *Triticum* plants raised under eight hours daily light bear almost normal green leaves whereas those grown under still shorter durations bear leaves with various shades ranging from yellowish-

TABLE I

**Chlorophyll content of the young-mature[2] leaves on the 50th day after germination in mgm. per unit dry weight*

Hours of light duration per day	*Triticum vulgare*	*Linum usitatissimum*	*Crotalaria juncea*
0[1]	..	..	..
1	2·3	1·9	3·7
2	2·4	2·1	4·3
4	2·8	2·3	6·5
6	3·0	2·8	7·3
8	3·3	3·2	8·6
12	3·4	3·4	9·8
15	3·5	3·6	10·2
18	3·6	3·7	10·8
24	3·7	3·7	11·0

* Each reading for chlorophyll content is an average of the determinations made in triplicate.

[1] The zero hour plants did not survive upto the 50th day and hence the chlorophyll content in these plants was examined only at later parts of their life-duration, *viz.*, from 15–30 days after germination.

[2] Physiologically intermediate between the extreme type of young and mature leaves.

green to golden-yellow. Under zero light, plants fail to produce the green pigment, at least in the later part of their life duration. The change in colour in this case is invariably associated with a change in the form of the leaves from the normal linear-lanceolate type to a narrow erect one. Such a change in form may be attributed to the differential development of the palisade tissue in the leaves, as emphasised by Haberlandt[15] in the case of Sycamore (*Acer Pseudoplatanus*) wherein double-sized palisade cells developed on a transference of plants from shade to sun. The few leaves that are formed on plants growing in darkness wither sooner or later, the dry areas proceeding from the margin inwards. In *Crotalaria*, a majority of the leaves shed, while the few that are left on the plants begin to lose their normal turgidity and gradually decay.

The *Triticum* plants illuminated for eight hours every day commence tillering on the 40th day against 35th of the control set receiving light for normal duration (twelve hours). Under still shorter duration of daily illumination, the tillering is considerably delayed inasmuch as that the plants growing in complete darkness fail to produce any tiller and die within a month of their germination. *Linum* growing under no light conditions as well as under one hour daily illumination assumes a recumbent growth habit with under-developed foliage of small size and yellow colour. In contrast to these, the two-hour exposed plants, although prostrate in the early stage, grow semi-erect subsequently, indicating the resumption of active growth with the increase of the period of illumination. Attenuation is another outstanding feature of almost all the plants illuminated for shorter durations than twelve hours every day. *Crotalaria* growing in complete darkness is found to droop and die only within a couple of weeks after germination.

Heading in *Triticum* illuminated for eight hours every day is delayed by ten days as compared to control, but in plants exposed for six and four hours daily, such a change results 4–5 weeks later (Table II). Illumination of plants for durations shorter than these is unfavourable for reproductive growth in *Triticum*. In *Linum*, however, six hours daily light supply is the minimal range for the production of floral organs, while in *Crotalaria* an exposure of plants for two hours every day is sufficient to induce flowering. Any decrease in the period of illumination beyond this range results in the complete absence of flowers. This indicates that the minimum light required for inducing floral development differs from crop to crop and that *Triticum* is adapted more to low-light conditions than *Linum*—a fact fully borne out by previous experiments on light-photosynthesis relationship[24] on some of these very crops when grown as mixed and competing for light side by side.

TABLE II

Influence of varying light duration upon certain aspects of plant growth

Particulars	Short Duration						Normal Duration	Long Duration		
	Zero light	1 hr.	2 hrs.	4 hrs.	6 hrs.	8 hrs.	12 hrs.	15 hrs.	18 hrs.	24 hrs.
					Triticum vulgare					
Average height per plant in cm. ..	21·00 ±0·279	20·60 ±0·550	31·50 ±0·394	36·40 ±0·762	41·00 ±0·501	49·50 ±0·617	55·00 ±0·478	61·50 ±0·877	62·00 ±0·981	62·60 ±0·970
Average number of tillers per plant ..	1·00 ±0·013	1·20 ±0·078	2·00 ±0·090	2·35 ±0·118	2·80 ±0·105	3·20 ±0·125	3·40 ±0·121	4·50 ±0·184	4·60 ±0·137	4·90 ±0·152
Final dry weight per plant in gm. ..	0·03 ±0·0008	0·27 ±0·006	1·14 ±0·035	2·49 ±0·062	3·66 ±0·055	4·85 ±0·081	6·97 ±0·174	7·69 ±0·180	7·84 ±0·172	7·60 ±0·210
Average length of heads in cm. ..	..	..	..	5·10 ±0·117	6·00 ±0·072	7·20 ±0·183	8·50 ±0·101	9·72 ±0·125	9·81 ±0·190	..
Average grain yield per plant in gm. ..	..	..	..	..	0·95 ±0·012	1·92 ±0·051	3·52 ±0·065	3·90 ±0·109	3·00 ±0·110	..
Absolute weight of 100 grains in gm. ..	..	..	..	..	2·80 ±0·100	3·04 ±0·117	4·35 ±0·111	4·55 ±0·140	4·70 ±0·151	..
Volume weight of grains per c.c. ..	..	..	..	..	0·41 ±0·012	0·54 ±0·035	0·66 ±0·071	0·69 ±0·082	0·70 ±0·073	..
Heading time in days	..	..	..	86	79	60	50	40	40	..
Duration of floral development in days	..	..	..	..	27	25	21	18	18	..
Fruiting stage in days	..	..	..	..	106	85	71	58	50	..
Age in days ..	30 (died)	78 (died)	120 (dried)	120 (dried)	120 (harvested)	113 (harvested)	106 (harvested)	92 (harvested)	92 (harvested)	120 (discontinued)
					Linum usitassimum					

Linum usitassimum

Average height per plant in cm. ..	4·60 ±0·162	9·50 ±0·181	14·00 ±0·303	24·50 ±0·211	27·20 ±0·227	30·60 ±0·385	32·50 ±0·540	34·20 ±0·782	38·00· ±0750	41·00 ±0·867
Final dry weight per plant in gm. ..	0·01 ±0·0002	0·12 ±0·003	0·25 ±0·008	0·80 ±0·012	0·81 ±0·005	1·62 ±0·050	2·93 ±0·055	3·60 ±0·131	3·72 ±0·115	4·61 ±0·182
Average grain yield per plant in gm. ..	..	..	..	..	..	1·17 ±0·025	1·94 ±0·032	2·40 ±0·101	2·78 ±0·061	..
Blossoming time in days	..	..	..	..	71	57	50	43	36	..
Duration of floral development in days ..	..	..	..	..	..	32	28	23	21	..
Fruiting stage in days	..	..	..	..	..	89	78	66	57	..
Age in days ..	22 (died)	71 (died)	92 (died)	106 (dried)	113 (dried)	113 (harvested)	106 (harvested)	92 (harvested)	85 (harvested)	113 (discontinued)

Crotalaria juncea

Average height per plant in cm. ..	20·50 ±0·310	31·50 ±0·240	43·50 ±0·521	49·60 ±0·810	50·20 ±0·497	98·40 ±0·622	106·20 ±0·780	108·70 ±0·901	110·00 ±0·990	118·50 ±0·872
Final dry weight per plant in gm. ..	0·35 ±0·017	0·48 ±0·024	0·60 ±0·054	1·70 ±0·058	2·45 ±0·101	4·22 ±0·201	6·20 ±0·155	7·00 ±0·342	7·61 ±0·227	8·45 ±0·245
Number of seed bearing pods	..	..	..	3·50 ±0·073	5·10 ±0·152	8·00 ±0·219	10·80 ±0·065	4·50 ±0·216	2·40 ±0·051	..
Average grain yield per plant in gm. ..	..	..	..	0·65 ±0·004	0·86 ±0·012	1·22 ±0·018	1·84 ±0·015	1·10 ±0·047	0·30 ±0·002	..
Blossoming time in days	..	..	43	43	43	43	43	78	91	..
Duration of floral development in days ..	..	..	..	34	34	27	21	20	15	..
Fruiting stage in days	..	..	..	77	77	70	64	98	106	..
Age in days ..	15 (died)	42 (died)	99 (dried)	99 (harvested)	99 (harvested)	99 (harvested)	99 (harvested)	120 (harvested)	141 (harvested)	141 (discontinued)

Crotalaria possesses a still greater tolerance to reduced duration of illumination.

The average number of spikelets per ear in the control *Triticum* plants, is 13, while the number of kernels is 26. In plants receiving eight hours light it is 11 and 20, in six hours illuminated plants 8 and 12, while in those receiving four hours light each day, only 6 sterile spikelets are formed. The small number of kernels in the six and eight hours exposed plants and the complete absence of any fructification in the four hour ones, clearly demonstrates that the decrease in the period of illumination below a certain specific minimum brings in sterility in the reproductive shoot.

Development of flowers and maturation of plants are greatly delayed in series illuminated for shorter durations than the normal (Table II). The root system is poorly developed in almost all such cases. Tillering in *Triticum* (Fig. 1) and branching in *Crotalaria* (Fig. 2) and *Linum* both decrease with the decrease in the photoperiod below the normal and these variations are associated with a definite quantitative decrease in the absolute dry matter accumulation and grain yield as well (Table II).

Long Duration Experiments—Morphological characteristics which are less susceptible to modification ordinarily, are greatly affected by the

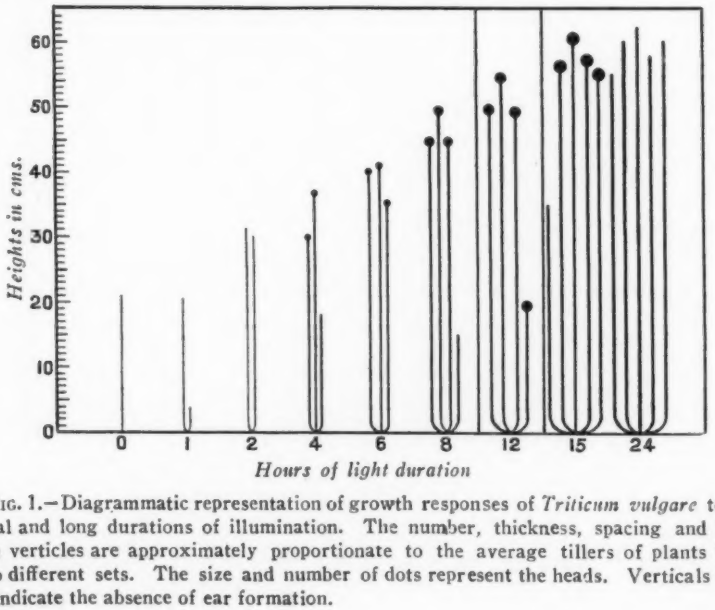

FIG. 1.—Diagrammatic representation of growth responses of *Triticum vulgare* to short, normal and long durations of illumination. The number, thickness, spacing and heights of the verticles are approximately proportionate to the average tillers of plants belonging to different sets. The size and number of dots represent the heads. Verticals without dots indicate the absence of ear formation.

lengthened light period. Plants illuminated for fifteen hours daily, exhibit many interesting features in this regard. In *Triticum*, *e.g.*, general improvement is noticed in the number of leaves, chlorophyll development, root ramification, general height, tillering capacity, culm elongation, peduncle length, head size, and grain formation (Table II and Fig. 1). These plants begin to tiller only a month after germination while the normal and the short-duration series of plants exhibit this phenomenon much later. Furthermore, they reproduce much earlier than the control and accordingly their age cycle is cut short by about two weeks. Consequent to these changes, the dry matter accumulation and grain yield are considerably increased. Under eighteen hours daily light, *Triticum* plants tend to grow more vegetatively losing in grain yield by about 30 per cent. as compared with plants receiving fifteen hours daily illumination. The decrease in yield is mainly due to the smaller number of heads produced. The total dry matter accumulated per plant, however, supersedes each of both the control and fifteen hours illuminated plants. In *Linum* too, under long light duration, the blossoming period is attained earlier than the control and so far as the general vigour and development of parts (foliage and floral) are concerned, this crop seems to be more adapted to the high grade of illumination, *viz.*, eighteen hours, in which case plants are ready to be harvested a week earlier than *Triticum* sown at the same time and grown under strictly identical conditions. Plants in this case grow tall and bushy bearing bigger leaves and greater number of flowers producing large plump grains in contrast to those grown under normal light duration. The grain yield increases by 43·2 per cent. over the control and by about 19·5 over those illuminated for fifteen hours daily (Table II).

Crotalaria plants grown under eighteen hours duration of light fail to bear any secondary branches (Fig. 2). Leaves of such plants become markedly big in size and deep green in colour, stems become stout and woody, and plants on the whole grow tall and leafy. With the advent of age lower leaves shed leaving one-third of the stem above soil almost naked. Blossoming in these plants takes place seven weeks later than the controls, so that when reproductive stage commences in them, the control plants are harvested (Table II). Flowers in this case are only confined to the apical region and are all fertile. Among the conspicuous formative effects of lengthened light period in *Crotalaria* is the pod size which is approximately double the size of those obtained from the check plants. Grains are superior in quality and the average number of these in this case is found to be ten per pod as against eight in the control. Nevertheless, long light duration in *Crotalaria* does not produce high yields of grain for the number of pods per plant is

greatly diminished, the production being only confined to apical regions (Fig. 2).

Plants which receive continuous illumination remain in a state of vegetive development throughout the trial when ultimately they are discarded.

Hordeum vulgare and *Gossypium herbaceum* yield best with fifteen hours duration of light, while *Brassica campestris* needs about eighteen hours daily illumination to achieve similar results. A limitation of space, however, precludes the detailed presentation of data for these crops.

Growth behaviour—It is a notable feature that with all variations induced as a result to photoperiodic response, the nature of growth remains practically similar in all the experimental sets. The sigmoid form is maintained in all the cases (*cf.* Singh[21])—although not so characteristically under lower light durations—indicating thereby that with alterations in the duration of light, it is mainly the magnitude of growth that is affected (Figs. 3 and 5). The absolute time-weight curves for *Triticum* grown under fifteen hours duration of light and *Linum* in eighteen hours, assume a much higher level than the normal and describe three phasic falls in succession. The coincidence of these falls with those in the growth-rate (Figs. 4 and 6) indicates that at these points plants grow less vigorously after a period of rapid increase.

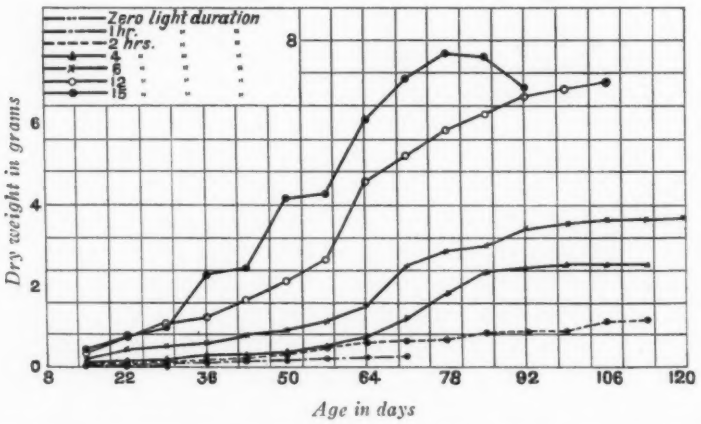

FIG. 3.—Time-weight curves for *Triticum* showing relative changes in dry matter accumulation of average entire plant at successive stages, grown in short, normal and long durations of illumination.

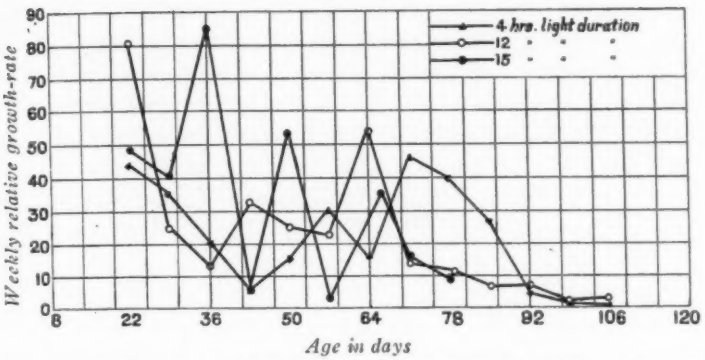

FIG. 4.—Representative weekly relative growth-rate curves for *Triticum*, grown in short, normal and long durations of illumination.

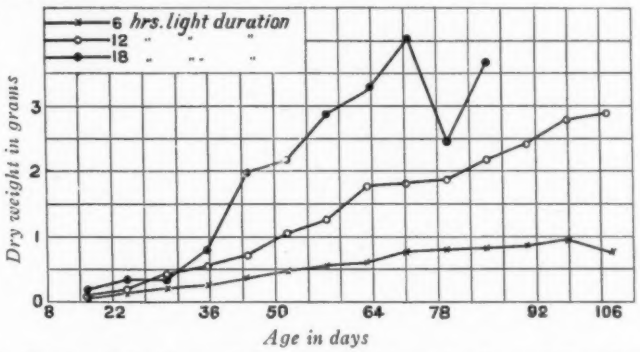

FIG. 5.—Representative time-weight curves for *Linum* showing relative changes in dry matter accumulation of average entire plant at successive stages grown in short, normal and long durations of illumination.

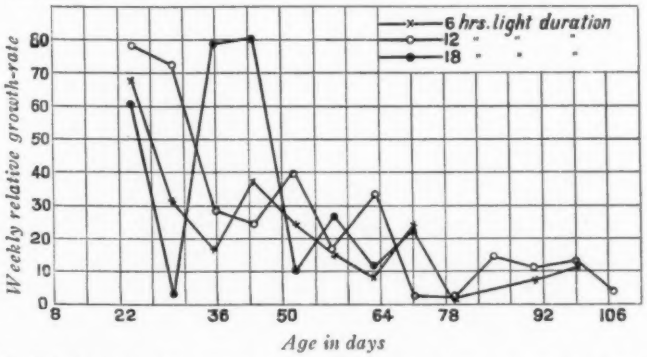

FIG. 6.—Weekly relative growth-rate curves for *Linum* grown in short, normal and long durations of illumination.

The growth-rate curves are characterised by a maximum at the approach of flowering and another at seeding exhibiting subsequently a decline (Figs. 4 and 6). In view of this fact, these humps appear earlier than in normal in some cases while later in others as the case may be, so that by mere looking at these curves, the degree of influence relative to light duration can at least partially be gauged. It is also observed that higher growth peaks are associated with higher yields and *vice versa*. Curves belonging to the short duration series, therefore, exhibit lower humps at a later stage than the control.

Light requirement—There is an abrupt quantitative variation in the biological response of plants to light duration (Table III) and hence to test the possibility of any existing correlation, the controlled variable, *viz.*, the light duration is plotted against dry matter and grain yields. The perceptible rise in dry weight with increasing light duration (Fig. 7) shows well that the variates are associated ; high dry matter production being in association with longer light duration and *vice versa*.

The distribution of the other groups of variates, *viz.*, grain yields and light duration (Fig. 8) is unimodal and skew type, where higher yields show a bias to right side. The skewness is, therefore, negative in character in

TABLE III

Light requirement of certain crop plants

Duration of daily illumination	Period of growth	Average dry matter per plant in gm.	Average grain yield per plant in gm.	Total hours of light	Light requirement in hours based on	
					Unit dry matter	Unit grain yield
		Triticum vulgare				
Zero	30	0·030 ± 0·0008	..	Zero	..	..
1 hr.	78	0·270 ± 0·006	..	78	288·8	..
2 hrs.	120	1·140 ± 0·035	..	240	210·5	..
4 ,,	120	2·490 ± 0·062	..	480	192·7	..
6 ,,	120	3·660 ± 0·055	0·952 ± 0·012	720	196·7	756·5
8 ,,	113	4·850 ± 0·081	1·920 ± 0·051	904	186·3	470·8
12 ,,	106	6·972 ± 0·174	3·522 ± 0·065	1272	182·4	361·1
15 ,,	92	7·692 ± 0·180	3·900 ± 0·109	1380	179·3	353·8
18 ,,	92	7·840 ± 0·172	3·000 ± 0·110	1656	211·2	552·0
24 ,,	120	7·600 ± 0·210	..	2880	378·9	..

TABLE III—*contd.*

Duration of daily illumination	Period of growth	Average dry matter per plant in gm.	Average grain yield per plant in gm.	Total hours of light	Light requirement in hours based on	
					Unit dry matter	Unit grain yield
		Linum usitatissimum				
Zero	22	0·010 ± 0·0002	..	Zero	..	..
1 hr.	71	0·120 ± 0·003	..	71	591·6	..
2 hrs.	92	0·250 ± 0·008	..	184	736·0	..
4 ,,	106	0·800 ± 0·012	..	424	530·0	..
6 ,,	113	0·810 ± 0·005	..	678	837·0	..
8 ,,	113	1·620 ± 0·050	1·170 ± 0·025	904	476·2	772·6
12 ,,	106	2·930 ± 0·055	1·940 ± 0·032	1272	434·1	655·6
15 ,,	92	3·600 ± 0·131	2·400 ± 0·101	1380	383·3	575·0
18 ,,	85	3·720 ± 0·115	2·780 ± 0·061	1530	375·0	550·3
24 ,,	113	4·610 ± 0·182	..	2712	588·2	..
		Crotalaria juncea				
Zero	15	0·349 ± 0·017	..	Zero	..	..
1 hr.	42	0·484 ± 0·024	..	42	86·7	..
2 hrs.	99	0·602 ± 0·054	..	198	328·9	..
4 ,,	99	1·700 ± 0·058	0·650 ± 0·004	396	232·9	738·4
6 ,,	99	2·450 ± 0·101	0·860 ± 0·012	594	242·4	837·2
8 ,,	99	4·220 ± 0·201	1·220 ± 0·018	792	187·6	740·9
12 ,,	99	6·200 ± 0·155	1·844 ± 0·015	1188	190·3	689·8
15 ,,	120	7·000 ± 0·342	1·100 ± 0·047	1800	257·1	1636·3
18 ,,	141	7·610 ± 0·227	0·306 ± 0·002	2538	335·5	5520·0
24 ,,	141	8·450 ± 0·245	..	3384	400·4	..

these cases. The yield diagrams illustrate well the differences in skewness for different crops, it being more towards the right for *Triticum* and *Linum* than *Crotalaria*. From these diagrams, it becomes clear that for grain formation only specific dosages of light are beneficial. *Triticum* yields best under fifteen hours daily illumination, *Linum* under eighteen, while *Crotalaria* requires only the normal duration, *viz.*, twelve hours.

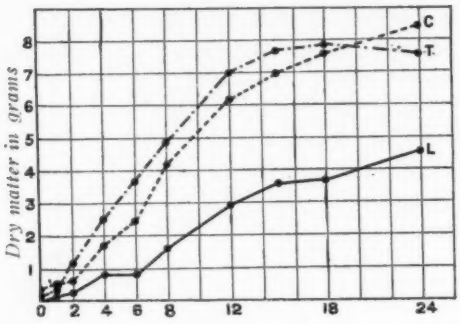

FIG. 7.—Final dry matter productions in (T)-*Triticum*, (L)-*Linum* and (C)-*Crotalaria* in relation to varying durations of daily illumination.

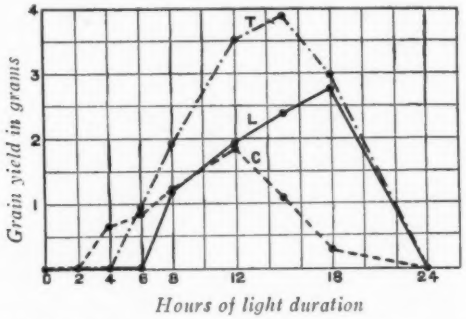

FIG. 8.—Grain yield diagrams in relation to varying durations of daily illumination for (T)-*Triticum*, (L)-*Linum* and (C)-*Crotalaria*.

The observations made in this investigation, obviously, indicate that both the production of dry matter and grain yield in plants are greatly influenced by the daily duration of the light supply. Analysis of data further points that the unit matter is produced at a much greater expenditure of light energy in case plants are grown under short durations of illumination than under relatively long (Table III). The same is true for very long durations as well. As a striking example in this regard, the response of *Crotalaria juncea* is cited (Table III) wherein the production of every unit of grain on plants grown under 18 hours daily illumination needs 8 times the light than those grown under 12 hours. It may be concluded that at or about the two extremes, *viz.*, darkness on the one hand and continuous light on the other, light exposures become either insufficient or oversufficient and with that the chances of reproduction become rare.

It is rather interesting to note that the maximum grain formation in plants takes place at the expense of minimum light energy per unit weight. The energy (light) requirements of different crops, however, do not tally. On a computation and comparison of the data obtained for a number of crops growing in the same season, it appears that oily crops like *Linum* and *Brassica* require greater light energy for the production of unit matter than crops like *Triticum* and *Hordeum* which are comparatively simple in their biochemic constitution. This end is, therefore, economically achieved in the former two crops under comparatively long duration of illumination (eighteen hours) than in the latter cases. A similar relation is observed to exsist in other experimental crops, *e.g.*, *Crotalaria* and *Gossypium* growing in a different season of the year. The need for a low optimum duration in case of *Crotalaria* appears very likely to be related to its characteristic adaptation to a different growing season. *Gossypium* grown in the same season, presumably for the same reason flourishes best under a light supply longer than *Crotalaria* but less than *Linum* and *Brassica*. This fact has also found elucidation in another communication[24] from this Experiment Station where the light-photosynthesis relationship has been worked out on some of these plants of different biochemic constitution.

By growing the plants under a set of controlled conditions and changing therein the light rationing, different types of growth are obtained ranging from complete sterility to a vigorous and healthy one, yielding superior progeny. Such a multiplicity of results is obtained with only an alteration in the duration of illumination, the intensity being constant. Importance of the light intensity has long been recognised by Harder[16] in his observations on *Phormidium foveolarum* which when cultivated in a strong light showed a higher rate of carbon assimilation than when grown in weak light and *vice versa*. According to Blackman and Matthæi[7] the amount of light required by a leaf is a specific value and that different leaves have different coefficients of acceleration of their assimilatory activity. It becomes apparent that the different competitors of a plant society have specific needs for not one but for both the components of illumination, *viz.*, the intensity and duration, and below a certain specific minimum either of these becomes limiting and an increase in that particular component alone brings about an increase in plant function.

It is thus obvious that the failure of mixed crops cannot exclusively be alluded to a deficit in soil nutrition but to a certain constellation of environmental conditions of which the disproportionate light rationing due to unsuitable selection of mixtures plays an important rôle. Frequent failure of

catch and subsidiary crops as also the rarity of weed flora in thickly grown fields are also attributable in part as after-effects of unfavourable light conditions. In the present investigation, not to an inconsiderable extent does the superior quality of grains depend upon slightly increased light feeding. Such conditions are amenable to experimental control and hence provide possibilities of the physiological isolation of desirable strains and their utilization in field investigation for evolving more suitable types.

Summary and Conclusions

The present investigation is aimed at a quantitative determination of the growth behaviour of certain crop plants in relation to alterations in the light duration. Recourse is taken to pot-culture experiments conducted under carefully controlled laboratory conditions. The photoperiod is varied in ten different sets from plants growing in complete darkness on the one hand to continuous illumination on the other. The data collected are tested for significance and analysed with special reference to crop production relative to light rationing.

In durations shorter than twelve hours, plants fail to grow normally. Development of chlorophyll and plant parts as also the production of dry matter and grain yields are retarded more and more with the decrease in the duration of illumination. Blossoming and maturation are generally delayed with the exception of plants growing under very short durations which die prematurely.

Plants behave differently when grown under long durations of illumination. *Crotalaria* thrives best in twelve hours ; *Hordeum, Gossypium* and *Triticum* in fifteen hours, while *Linum* and *Brassica* need eighteen hours daily illumination. With changes in the photoperiod, however, the growth mechanism of plants remains more or less unaffected.

The occurrence of sexual reproduction in plants is only confined to certain specific limits, below which they tend to become sterile while beyond that giant growth sets in.

The need for light among the different competitors of a plant society differs widely from crop to crop ; those having simpler end-products seem to need less light than the more complex ones. Plants of more or less similar constitutions growing in different seasons of the year also differ markedly in their light requirement due perhaps to seasonal adaptations.

LITERATURE CITED

1. Adams, J. .. "Relation of flax to varying amounts of light," *Bot. Gaz.*, 1920, **70**, 153–156.
2. ———— .. "The effect on certain plants of altering the daily period of light," *Ann. Bot.*, 1923, **37**, 72–94.
3. ———— .. "Does light determine the date of heading out in winter wheat and winter rye?" *Amer. Jour. Bot.*, 1924, **11**, 535–539.
4. ———— .. "Duration of light and growth," *Ann. Bot.*, 1924, **38**, 510–523.
5. ———— .. "The effect on tomato, soybean, and other plants of altering the daily period of light," *Amer. Jour. Bot.*, 1924, **11**, 229–233.
6. ———— .. "Some further experiments on the relation of light to growth," *ibid.*, 1925, **12**, 398–413.
7. Blackman, F. F., and Matthæi, G. L. C. "Experimental researches in vegetable assimilation and respiration. IV. A quantitative study of carbon dioxide assimilation and leaf-temperature in natural illumination," *Proc. Roy. Soc.* (B), 1905, **76**, 402–460.
8. Deats, M. E. .. "The effect on plants of the increase and decrease of the period of illumination over that of the normal day period," *Amer. Jour. Bot.*, 1925, **12**, 384–394.
9. Eaton, F. M. .. "Assimilation-respiration balance as related to length of day reactions in soybeans," *Bot. Gaz.*, 1924, **77**, 311–321.
10. Garner, W. W., and Allard, H. A. "Effect of relative length of day and night and other factors of the environment on growth and reproduction in plants," *Jour. Agric. Res.*, 1920, **18**, 533–606.
11. ———— .. "Further studies in photoperiodism. The response of the plants to relative length of day and night," *ibid.*, 1923, **23**, 871–921.
12. ———— .. "Localization of the response in plants to relative length of day and night," *ibid.*, 1925, **31**, 555–567.
13. ———— .. "Effect of short alternating periods of light and darkness on plant growth," *Science, N.S.*, 1927, **66**, 40–42.
14. ———, Bacon, C. W., and Allard, H. A. "Photoperiodism in relation to hydrogen-ion concentration of the cell sap and the carbohydrate content of the plant," *Jour. Agric. Res.*, 1924, **27**, 119–156.
15. Haberlandt, G. .. *Physiological Plant Anatomy*, Macmillan & Co., Ltd., London, 1928, 293–297.
16. Harder, R. .. "Über die bedeutung von lichtintensität und wellenlänge für die assimilation farbiger algen," *Zeitschr. f. Bot.*, 1923, **15**, 305–355.
17. Klebs, G. .. "Ueber die Blütenbildung von Sempervivum," *Flora, N.F.*, 1918, **11–12** (Stahl-Festschrift), 128–151.
18. McClelland, T. B. .. "Studies of the photoperiodism of some economic plants," *Jour. Agric. Res.*, 1928, **37**, 603–628.

19. Nightingale, G. T. .. "Light in relation to the growth and chemical composition of some horticultural plants," *Amer. Soc. Hort. Sci. Proc.*, 1922, **19**, 18–29.

20. Oltman, R. E. .. "A new method and instrument for the quantitative determination of chlorophyll," *Plant Physiol.*, 1933, **8**, No. 2, 321–326 and (special communication of the author).

21. Singh, B. N. .. "The basis of ageing, rejuvenation and death—being an experimental study in the physiology and chemistry of plant material," *Malaviya Commemoration Volume*, Indian Press, Allahabad, India, 1932.

22. ————, and Choudhri, R. S. "Induced morphological, physiological and chemical variations following seed-exposure to X-radiation in *Nicotiana tabacum*," *Proc. Ind. Acad. Sci.*, 1935, **1**, No. 8.

23. ————, and Kumar, K. "The reactions of the assimilatory system to alterations of light intensity," *ibid.*, 1935, **1**, No. 11.

24. ————, and Lal, K. N. "Photosynthetic specificity in relation to biochemic constitution" (in course of publication).

25. Tincker, M. A. H. .. "Effect of length of day on flowering and growth," *Nature*, 1924, **114**, 350–351.

26. ———————— .. "The effect of length of day upon the growth and reproduction of some economic plants," *Ann. Bot.*, 1925, **39**, 721–754.

27. ———————— .. "The effect of length of day upon the growth and chemical composition of the tissues of certain economic plants," *ibid.*, 1928, **42**, 101–140.

28. ———————— .. "The effect of length of day on plants," *Jour. Roy. Hort. Soc.*, 1929, **54**, 354–378.

29. Turesson, G. .. "The cause of plagiotropy in maritime shore plants," *Lunds Univers. Arsskr. Avd. II*, 1919, **16**, No. 2.

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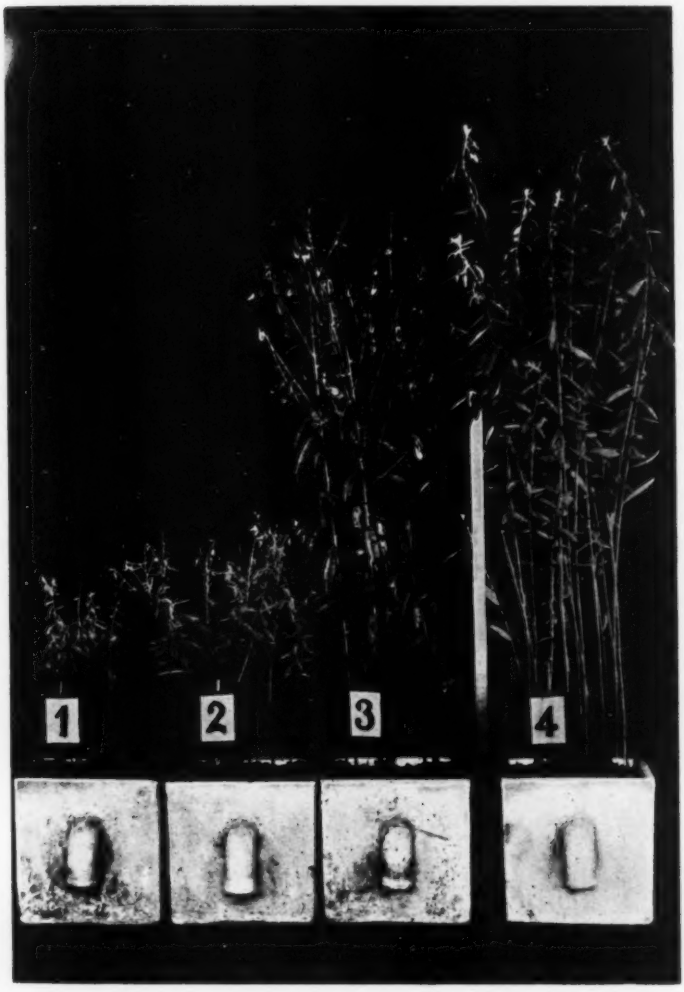

FIG. 2—Relative effects in *Crotalaria* grown under short, normal and long durations of illumination: (1) Two hours daily; (2) Four hrs. daily; (3) Twelve hrs. daily; (4) Eighteen hrs. daily.

STUDIES IN SORGHUM—INTERNODES AND LEAF-SHEATHS.

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Sorghum is the predominant cereal suited to regions of scanty rainfall. It is the important food crop of the poor cultivators. In America both the grain and the straw of most of the sorghum cultivated there, is used as food for animals. In Asia and Africa, sorghum is a food crop for both man and beast. Among the rain-fed annual cereals, sorghum produces the largest total weight of both grain and straw. There have been instances of sorghum producing about 4,000 pounds per acre under rain-fed conditions in Coimbatore, and of this about 3,400 pounds represent straw weight. The fodder part of the sorghum crop is thus very valuable. The importance of sorghum straw to animal husbandry and the reactions of the prosperity of that husbandry on the cultivator, need no stressing. In sorghum straw, we have a fodder of great keeping quality and the huge stacks that stud the countryside betoken the importance of this cattle food.

The straw of sorghum consists mostly of internodes and leaf-sheaths. Within the hard rind of the internodes there is stored, fresh and nice, the sweet smelling pith and anyone that notices the zest with which cattle nibble the freshly chopped sorghum straw, will realise in what excellent condition this fine cattle food is preserved.

Apart from a few cultivators that could grow the sorghum crop purely for fodder, the majority among them grow it for grain and fodder. The volume of the sorghum straw is determined by the height and the thickness of its stalk. Given wide spacing, some sorghum varieties are capable of increasing the thickness of their stalks even to the size of sugarcane. There is, however, a limit to the spacing that could be given to a crop without sacrificing its yield. This spacing is determined by soil and climatic conditions. The thickness of the stalk will therefore depend on the optimum population per acre. With more than the average width of spacings, the

straw tends to be very coarse and to that degree less agreeable to cattle. The rejected straw, however, increases the available litter and often augments the thatch and fuel resources of the cultivator.

This article records some of the metrical attributes of the internode, the leaf-sheath and the node in some of the typical varieties of sorghum. Such important attributes of sorghum straw, like sweetness and juiciness, have proved heritable characters and the mode of their inheritance has already been worked out.[1, 2]

Height and Duration.

Sieglinger[3] working on the sorghum found a high correlation between the number of leaves and the length of the vegetative period. The general impression that is gathered after a study of the many varieties grown at Coimbatore is, that the longer the duration of a veriety, the taller is the plant produced. Exceptions to this general rule would easily occur to a sorghum worker. A striking exception is the *Tella Jonna* of the Bellary tract. The heads are heavy and the stalks are mostly juicy and are therefore heavy. This heaviness has necessitated a build to the plant, which is short and stubby relatively to its duration. Table I gives data from

TABLE I.

Duration and Height in Sorghum.

Selection No.	Name of Variety		Average Duration	Average Height
			Days	cm.
M.S. 3102	Early Kalo Near *Sorghum caffrorum*, Beauv.	Kansas	80	100
„ 3107	Greeley Near *Sorghum bicolor* (Linn.)	Kansas	85	120
A.S. 3460	Feterita *Sorghum caudatum*, Stapf. var. *Feterita*, Stapf.	Texas	90	140
„ 1751	Feterita *S. caudatum*, Stapf. var. *Feterita*, Stapf.	China	95	145
„ 578	Pedda Jonna (Edu Akula Jonna) *Sorghum durra*, Stapf.	S. India	100	160
„ 1561	Uppam Cholam *Sorghum subglabrescens* var. *irungiforme* (Burkill), Snowden	S. India	105	165

TABLE I—(*Contd.*).

Selection No.	Name of Variety	Average Duration	Average Height
A.S. 1186	Chinna Manjal Cholam S. India *S. subglabrescens* var. *compactum* (Burkill), Snowden	110	210
„ 1231	Sen Cholam S. India *S. subglabrescens* var. *rubidum* (Burkill), Snowden	115	215
„ 4261	Songu Cholam S. India *S. dochna* (Forsk.) var. *irungu* (Burkill), Snowden	120	220
„ 1050	Irungu Cholam S. India *S. dochna* (Forsk.) var. *irungu* (Burkill), Snowden	125	225
„ 60	Peria Manjal Cholam S. India *S. durra*, Stapf. var. *Coimbatoricum* (Burkill), Snowden	130	230
„ 3550	Peria Manjal Cholam S. India *S. durra*, Stapf. var. *Coimbatoricum* (Burkill), Snowden	135	235
„ 4695	Jonna Ganjam S. India *Sorghum Roxburghii*, Stapf. var. *hians*, Stapf.	140	240
„ 4078	Makra Jola S. India *S. Roxburghii*, Stapf. var. *hians*, Stapf.	145	250
„ 3944	" Jebere " Tanganyika *Sorghum conspicuum*, Snowden var. *usaramense* (Busse et Pilger), Snowden	150	260
A.S. 4294	Konda Jonna S. India *Sorghum Roxburghii*, Stapf. var. *hians*, Stapf.	155	265
M.S. 1142	" Zomba " Sierra Leone *Sorghum margaritiferum*, Stapf.	160	270
A.S. 3958	" Topeka " Tanganyika *Sorghum conspicuum*, Snowden var. *usaramense* (Busse et Pilger), Snowden	165	310
„ 3971	" Karachi " Tanganyika *S. conspicuum*, Snowden var. *conspicuum*, Snowden	170	350

typical varieties showing the general trend of relationship between height and duration. This is graphically presented in Fig. 1.

The components of this character-composite called height, in this usually single stalked giant cereal, were examined. The stalk of sorghum

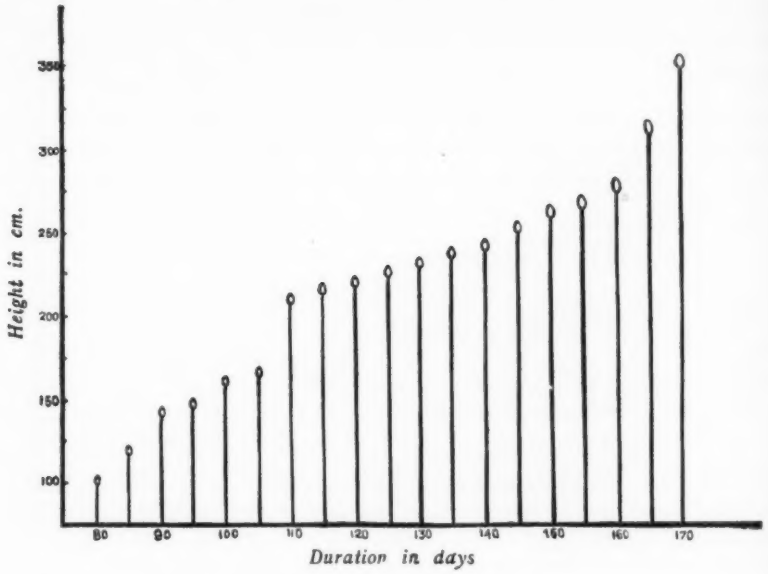

FIG. 1.
Height Tends to Increase with Duration.

consists of a series of internodes placed one above the other. The height of the plant is the sum total of lengths constituting the individual internodal lengths.

Three Types of Internodal Disposition.

Sorghums can be broadly classified into three groups in their duration: (1) Early—75 to 100 days, (2) Medium—100 to 130 days and (3) Late—130 to 170 days. In the early duration group, the number of internodes (always those above ground level being counted) ranges from 7 to 10. The internodes tend to increase in their individual length from the base upward until they end with a long peduncle. These varieties are few leaved and one varietal name *Edu Akula Jonna*—Seven Leaved Sorghum—is connotative of the type that prevails in this group. Every leaf arises from a node, and barring the minute lower leaves that dry and die off, seven is the common leaf number in a crop of this duration. Table II summarises measurements made in this group of short early plants characterised by few nodes and a *steady internodal increase.* The measurements are the average of 10 typical plants in each variety. The short duration of most of these varieties does not fit them for the longer growth period of the main rain-fed season, but most of these do very well as short duration irrigated crops. Under rainfed

TABLE II.

TABLE II.

Internodal Type 1—*Steady Internodal Increase.*

Early Duration Group—80–100 *Days.*

Selection No.	Name of Variety		Length of internode from bottom upwards to peduncle—in cm. (Average of 10 readings)									
			1	2	3	4	5	6	7	8	9	10
A.S. 1751	Feterita *Sorghum caudatum*, Stapf. var. *Feterita*, Stapf.	China	0·4	1·5	3·7	8·0	11·4	14·3	15·5	17·6	20·0	50·2
„ 3460	Feterita *S. caudatum*, Stapf. var. *Feterita*, Stapf.	Texas	1·1	2·5	5·5	8·4	11·5	12·3	14·0	16·0	18·7	48·5
„ 1745	Feterita *S. caudatum*, Stapf. var. *Feterita*, Stapf.	Texas	1·0	1·6	4·5	6·3	6·4	8·0	10·3	10·5	37·5	
„ 578	Pedda Jonna (Edu Akula Jonna) *Sorghum durra*, Stapf.	S. India	1·8	4·9	11·3	19·6	20·4	25·2	30·9	49·7		
„ 2876	Dawn Kafir *Sorghum caffrorum*, Beauv. var. *albidum* (Koern), Snowden	China	2·0	5·9	8·7	18·1	22·0	23·7	27·0	70·5		
M.S. 3076	Elton Sorgo Near *Sorghum dochna* (Forsk.), Snowden	Texas	1·3	2·8	7·0	11·5	12·0	15·5	38·0			
„ 3102	Early Kalo Near *S. caffrorum*, Beauv.	Kansas	1·1	1·6	2·8	6·9	12·3	15·0	38·5			

conditions they will suit light loamy soils that receive favourable rainfall in the early stages of growth, thus ensuring quick development and ripening.

The second group consists of varieties with a duration from 100 to 130 days. The number of internodes ranges from 12 to 16. This group is the largest in sorghums, its duration being intermediate between the two extremes. In this group the peduncle is usually longer than any internode. This group differs from the previous one in that, instead of a steady increase in the internodal length leading up to the markedly long peduncle, there is a steady increase till about the middle internode of the plant from whence the internodes tend to shorten a bit and lengthen again till the peduncle is reached. This is called the *unimodal* type. Internodal measurements of typical varieties in this group are given in Table III.

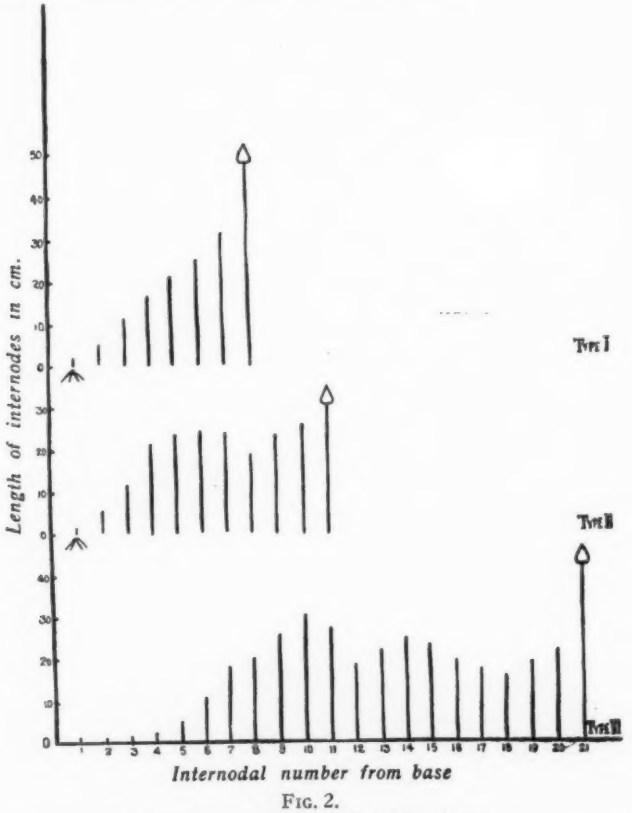

FIG. 2.
Three Types of Internodal Dispositions.
Type I : Uniform Increase. *Type II : Unimodal.* *Type III : Bimodal.*

TABLE III.

Internodal Type 2—Unimodal Internodal Disposi
Medium Duration Group—100–130 *Days.*

Selection No.	Name of Variety	Length of internode from bottom						
		1	2	3	4	5	6	7
M.S. 2133	Black Hull Kafir Texas *Sorghum caffrorum*, Beauv. var. *albofuscum* (Koern), Snowden	0·5	1·9	3·1	4·4	6·2	7·2	7·
„ 1495	Kampupu N. Rhodesia *Sorghum nigricans* (Ruiz et Pavon) var. *cerevisiæ* (Stapf.), Snowden	0·3	0·4	0·6	0·8	4·6	8·8	10·
„ 2379	Sunrise Kafir Texas *Sorghum caffrorum*, Beauv. var. *albofuscum* (Koern), Snowden	0·3	0·7	2·5	5·4	9·6	13·3	14·
„ 2395	White yolo Texas *Sorghum caffrorum*, Beauv. var. *albofuscum* (Koern), Snowden	0·5	1·1	2·1	4·9	9·6	10·8	13·
„ 1456	Masabi Texas *Sorghum guineense*, Stapf. var. *involutum*, Stapf.	0·4	0·6	0·8	1·2	3·7	10·9	19·
A.S. 22	Peria Manjal Cholam S. India *Sorghum durra*, Stapf. var. *Coimbatoricum* (Burkill), Snowden	6·2	13·5	16·2	21·0	22·5	23·5	29·
„ 60	Peria Manjal Cholam Somayanur, S. India *Sorghum durra*, Stapf. var. *Coimbatoricum* (Burkill), Snowden	9·4	18·4	21·2	21·7	23·9	25·0	26·
„ 477	Nar Cholam Koilpatti, Tinnevelley Dt., S. India *Sorghum dochna* (Forsk.), Snowden var. *irungu* (Burkill), Snowden	9·8	11·2	12·6	13·5	18·6	25·2	26·
T_1	Tella Jonna Hagari, S. India *Sorghum cernuum*, Host var. *globosum* (Hack), Snowden	0·3	5·0	9·5	11·3	11·4	12·0	11·
A.S. 1565	Pilla Jonna Guntur, S. India *Sorghum durra*, Stapf.	2·5	9·1	15·3	15·7	16·3	15·0	14·
„ 1186	Chitrai Vellai S. India *Sorghum subglabrescens*, Schweinf et Aschers var. *irungiforme* (Burkill), Snowden	1·0	9·5	18·8	22·5	23·4	21·8	20·
„ 2155	Chitrai Vellai S. India *Sorghum subglabrescens*, Schweinf et Aschers var. *irungiforme* (Burkill), Snowden	4·0	13·5	20·5	22·3	22·7	26·5	26·
„ 1543	Vellai cholam S. India *Sorghum subglabrescens*, Schweinf et Aschers var. *irungiforme* (Burkill), Snowden	1·5	4·2	16·3	24·6	25·6	25·7	26·
„ 732	Chitrai Vellai Central Farm, S. India *Sorghum subglabrescens*, Schweinf et Aschers var. *irungiforme* (Burkill), Snowden	2·6	12·7	21·3	25·0	26·3	23·5	23·
„ 63	Peria Manjal Cholam Edayarpalayam, S. India *Sorghum durra*, Stapf. var. *Coimbatoricum* (Burkill), Snowden	4·8	14·8	17·8	24·7	27·3	25·8	25·
M.S. 3154/*d*	Sudan Grass S. India *Sorghum sudanense*, Stapf.	2·3	4·0	7·2	12·2	14·5	16·0	17·
T_{12}	Tella Jonna S. India *Sorghum cernuum*, Host var. *globosum* (Hack), Snowden	0·6	4·1	10·6	12·8	13·0	12·4	11·

TABLE III.

Internodal Type 2—Unimodal Internodal Disposit
Medium Duration Group—100–130 *Days.*

	Length of internode from bottom u						
	1	2	3	4	5	6	7
Texas	0·5	1·9	3·1	4·4	6·2	7·2	7·
N. Rhodesia	0·3	0·4	0·6	0·8	4·6	8·8	10·
Texas	0·3	0·7	2·5	5·4	9·6	13·3	14·
Texas	0·5	1·1	2·1	4·9	9·6	10·8	13·
Texas	0·4	0·6	0·8	1·2	3·7	10·9	19·
S. India	6·2	13·5	16·2	21·0	22·5	23·5	29·
n yanur, S. India	9·4	18·4	21·2	21·7	23·9	25·0	26·
n y Dt., S. India	9·8	11·2	12·6	13·5	18·6	25·2	26·
Hagari, S. India	0·3	5·0	9·5	11·3	11·4	12·0	11·
untur, S. India	2·5	9·1	15·3	15·7	16·3	15·0	14
S. India Aschers	1·0	9·5	18·8	22·5	23·4	21·8	20
S. India Aschers	4·0	13·5	20·5	22·3	22·7	26·5	26
S. India Aschers	1·5	4·2	16·3	24·6	25·6	25·7	26
Farm, S. India Aschers	2·6	12·7	21·3	25·0	26·3	23·5	23
ayam, S. India	4·8	14·8	17·8	24·7	27·3	25·8	25
en S. India	2·3	4·0	7·2	12·2	14·5	16·0	17
S. India	0·6	4·1	10·6	12·8	13·0	12·4	11

odal Disposition.
130 Days.

from bottom upwards to peduncle in cm. (Average of 10 readings)

	6	7	8	9	10	11	12	13	14	15	16
2	7·2	7·4	7·4	8·0	8·2	8·2	8·1	7·2	5·6	7·9	38·5
·6	8·8	10·8	14·6	15·5	16·0	19·7	18·5	17·3	14·4	43·0	
·6	13·3	14·5	12·8	11·8	11·4	14·1	14·8	17·4	44·2		
·6	10·8	13·1	11·0	8·9	8·3	7·8	8·5	11·4	35·1		
·7	10·9	19·5	24·6	30·4	28·7	26·6	28·8	30·0	67·5		
·5	23·5	29·0	28·2	24·5	23·0	26·0	28·8	54·0			
·9	25·0	26·2	25·0	22·7	24·5	27·0	27·2	47·5			
·6	25·2	26·4	25·5	23·9	21·8	19·9	22·3	73·9			
·4	12·0	11·0	9·5	7·5	7·2	7·0	14·0				
·3	15·0	14·0	13·0	14·0	14·0	14·6	22·5				
·4	21·8	20·4	18·2	17·0	14·5	11·2	29·8				
·7	26·5	26·8	23·3	19·3	17·5	16·0	28·5				
·6	25·7	26·0	25·6	25·4	22·3	17·6	27·5				
·3	23·5	23·3	21·3	20·0	20·7	23·4	30·2				
·3	25·8	25·2	28·8	29·4	30·9	33·8	51·8				
·5	16·0	17·1	14·8	15·6	16·7	18·0	55·0				
·0	12·4	11·6	11·0	9·6	9·1	20·3					

TABLE II

Internodal Type 2—Uni
Medium Duration

Selection No.	Name of Variety	Length of			
		1	2	3	
A.S. 2095	Vellai Cholam S. India *Sorghum subglabrescens*, Schweinf et Aschers var. *irungiforme* (Burkill), Snowden	2·0	7·0	12·0	
„ 1561	Uppam Cholam Coimbatore, S. India *Sorghum subglabrescens*, Schweinf et Aschers var. *irungiforme* (Burkill), Snowden	2·3	3·8	16·6	
„ 374	Chinna Manjal Cholam Coimbatore, S. India *Sorghum subglabrescens*, Schweinf, et Aschers var. *compactum* (Burkill), Snowden	1·0	4·0	10·7	
„ 809	Chinna Manjal Cholam Coimbatore, S. India *Sorghum subglabrescens*, Schweinf et Aschers var. *compactum* (Burkill), Snowden	1·2	5·0	11·6	
„ 1625	Sen Cholam Salem, S. India *Sorghum subglabrescens*, Schweinf et Aschers var. *rubidum* (Burkill), Snowden	2·0	10·7	16·5	
„ 1546	Chitrai Vellai S.India *Sorghum subglabrescens*, Schweinf et Aschers var. *irungiforme* (Burkill), Snowden	2·5	9·0	15·4	
„ 1050	Sevvirungu Kodai Road, S. India *Sorghum dochna* (Forsk), Snowden var. *irungu* (Burkill), Snowden	1·3	4·3	11·7	
„ 1656	Chitrai Vellai S. India *Sorghum subglabrescens*, Schweinf et Aschers var. *irungiforme* (Burkill), Snowden	7·4	17·0	19·9	
„ 360	Silapadi Vellai Ettamanaikenpatti, S. India *Sorghum subglabrescens*, Schweinf et Aschers var. *irungiforme* (Burkill), Snowden	3·3	9·6	17·6	
„ 1425	From Karun Cholam Pallapatti, S. India *Sorghum dochna* (Forsk.), Snowden var. *irungu* (Burkill), Snowden	1·0	6·8	11·6	
„ 356	Ennaikittan Cholam Dindigul, S. India *Sorghum subglabrescens*, Schweinf et Aschers var. *irungiforme* (Burkill), Snowden	1·2	7·2	14·5	
„ 1019	Ennaikittan Cholam Dindigul, S. India *Sorghum subglabrescens*, Schweinf et Aschers var. *irungiforme* (Burkill), Snowden	1·2	7·6	13·7	
„ 3700	Broom Corn Bihar and Orissa *Sorghum dochna* (Forsk.), Snowden var. *technicum*, Snowden	2·4	9·2	18·5	
„ 2137	Kullan Cholam Coimbatore, S. India *Sorghum subglabrescens*, Schweinf et Aschers var. *compactum* (Burkill), Snowden	2·2	10·2	19·0	
„ 790	Uppam Cholam Coimbatore, S. India *Sorghum subglabrescens*, Schweinf et Aschers var. *irungiforme* (Burkill), Snowden	1·2	10·2	17·8	
„ 1195	Chinna Manjal Cholam Coimbatore, S. India *Sorghum subglabrescens*, Schweinf et Aschers var. *compactum* (Burkill), Snowden	3·5	13·8	22·5	
„ 380	Ennaikittan Cholam Coimbatore, S. India *Sorghum subglabrescens*, Schweinf et Aschers var. *irungiforme* (Burkill), Snowden	1·5	7·5	16·7	

TABLE III (*Contd.*).

Type 2—Unimodal Internodal Disposition.
um Duration Group—100–130 *Days.*

Length of Internode from bottom upwards to Peduncle in cms. (Average of 10 readings)

2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
7·0	12·0	15·0	19·8	20·9	21·1	20·3	14·3	9·6	25·3					
3·8	16·6	18·6	21·5	19·4	17·8	16·6	13·2	15·3	24·6					
4·0	10·7	17·8	21·0	21·6	21·8	17·2	18·4	18·9	24·5					
5·0	11·6	20·7	22·3	22·4	21·5	18·2	22·9	24·6	30·0					
10·7	16·5	21·5	22·3	21·8	21·6	18·6	17·7	20·6	27·0					
9·0	15·4	19·6	21·4	22·8	22·8	21·5	19·5	19·2	29·0					
4·3	11·7	16·0	21·8	24·8	21·0	23·0	24·6	25·5	57·0					
17·0	19·9	20·1	25·0	27·0	22·5	20·3	20·1	21·0	31·3					
9·6	17·6	20·5	22·8	25·0	22·5	25·5	25·5	27·6	39·3					
6·8	11·6	16·7	21·3	22·3	24·8	25·0	23·4	28·9	68·5					
7·2	14·5	19·2	20·5	20·6	19·0	16·2	16·1	24·0						
7·6	13·7	20·2	22·4	20·0	19·8	15·0	17·6	27·2						
9·2	18·5	19·7	23·0	21·0	15·3	14·2	17·3	36·0						
10·2	19·0	22·0	23·8	23·8	20·3	20·3	20·0	25·2						
10·2	17·8	22·0	22·9	22·3	22·3	20·2	22·1	26·4						
13·8	22·5	22·8	23·5	21·7	21·2	14·6	17·3	29·8						
7·5	16·7	21·8	23·9	23·6	21·4	19·7	31·1							

No.		1	2	3
A.S. 2095	Vellai Cholam S. India *Sorghum subglabrescens*, Schweinf et Aschers var. *irungiforme* (Burkill), Snowden	2·0	7·0	12·0
„ 1561	Uppam Cholam Coimbatore, S. India *Sorghum subglabrescens*, Schweinf et Aschers var. *irungiforme* (Burkill), Snowden	2·3	3·8	16·6
„ 374	Chinna Manjal Cholam Coimbatore, S. India *Sorghum subglabrescens*, Schweinf, et Aschers var. *compactum* (Burkill), Snowden	1·0	4·0	10·7
„ 809	Chinna Manjal Cholam Coimbatore, S. India *Sorghum subglabrescens*, Schweinf et Aschers var. *compactum* (Burkill), Snowden	1·2	5·0	11·6
„ 1625	Sen Cholam Salem, S. India *Sorghum subglabrescens*, Schweinf et Aschers var. *rubidum* (Burkill), Snowden	2·0	10·7	16·5
„ 1546	Chitrai Vellai S.India *Sorghum subglabrescens*, Schweinf et Aschers var. *irungiforme* (Burkill), Snowden	2·5	9·0	15·4
„ 1050	Sevvirungu Kodai Road, S. India *Sorghum dochna* (Forsk), Snowden var. *irungu* (Burkill), Snowden	1·3	4·3	11·7
„ 1656	Chitrai Vellai S. India *Sorghum subglabrescens*, Schweinf et Aschers var. *irungiforme* (Burkill), Snowden	7·4	17·0	19·9
„ 360	Silapadi Vellai Ettamanaikenpatti, S. India *Sorghum subglabrescens*, Schweinf et Aschers var. *irungiforme* (Burkill), Snowden	3·3	9·6	17·6
„ 1425	From Karun Cholam Pallapatti, S. India *Sorghum dochna* (Forsk.), Snowden var. *irungu* (Burkill), Snowden	1·0	6·8	11·6
„ 356	Ennaikittan Cholam Dindigul, S. India *Sorghum subglabrescens*, Schweinf et Aschers var. *irungiforme* (Burkill), Snowden	1·2	7·2	14·5
„ 1019	Ennaikittan Cholam Dindigul, S. India *Sorghum subglabrescens*, Schweinf et Aschers var. *irungiforme* (Burkill), Snowden	1·2	7·6	13·7
„ 3700	Broom Corn Bihar and Orissa *Sorghum dochna* (Forsk.), Snowden var. *technicum*, Snowden	2·4	9·2	18·5
„ 2137	Kullan Cholam Coimbatore, S. India *Sorghum subglabrescens*, Schweinf et Aschers var. *compactum* (Burkill), Snowden	2·2	10·2	19·0
„ 790	Uppam Cholam Coimbatore, S. India *Sorghum subglabrescens*, Schweinf et Aschers var. *irungiforme* (Burkill), Snowden	1·2	10·2	17·8
„ 1195	Chinna Manjal Cholam Coimbatore, S. India *Sorghum subglabrescens*, Schweinf et Aschers var. *compactum* (Burkill), Snowden	3·5	13·8	22·5
„ 380	Ennaikittan Cholam Coimbatore, S. India *Sorghum subglabrescens*, Schweinf et Aschers var. *irungiforme* (Burkill), Snowden	1·5	7·5	16·7
„ 1057	Uppam Cholam Coimbatore, S. India *Sorghum subglabrescens*, Schweinf et Aschers var. *irungiforme* (Burkill), Snowden	1·4	7·8	15·2

2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
7·0	12·0	15·0	19·8	20·9	21·1	20·3	14·3	9·6	25·3					
3·8	16·6	18·6	21·5	19·4	17·8	16·6	13·2	15·3	24·6					
4·0	10·7	17·8	21·0	21·6	21·8	17·2	18·4	18·9	24·5					
5·0	11·6	20·7	22·3	22·4	21·5	18·2	22·9	24·6	30·0					
10·7	16·5	21·5	22·3	21·8	21·6	18·6	17·7	20·6	27·0					
9·0	15·4	19·6	21·4	22·8	22·8	21·5	19·5	19·2	29·0					
4·3	11·7	16·0	21·8	24·8	21·0	23·0	24·6	25·5	57·0					
17·0	19·9	20·1	25·0	27·0	22·5	20·3	20·1	21·0	31·3					
9·6	17·6	20·5	22·8	25·0	22·5	25·5	25·5	27·6	39·3					
6·8	11·6	16·7	21·3	22·3	24·8	25·0	23·4	28·9	68·5					
7·2	14·5	19·2	20·5	20·6	19·0	16·2	16·1	24·0						
7·6	13·7	20·2	22·4	20·0	19·8	15·0	17·6	27·2						
9·2	18·5	19·7	23·0	21·0	15·3	14·2	17·3	36·0						
10·2	19·0	22·0	23·8	23·8	20·3	20·3	20·0	25·2						
10·2	17·8	22·0	22·9	22·3	22·3	20·2	22·1	26·4						
13·8	22·5	22·8	23·5	21·7	21·2	14·6	17·3	29·8						
7·5	16·7	21·8	23·9	23·6	21·4	19·7	31·1							
7·8	15·2	19·1	22·2	23·5	23·0	24·7	31·0							

TABLE IV.

Internodal Type 3—*Bimodal Internod*
Late Duration Group—130–17

Selection No.	Name of Variety		Length of internode from b								
			1	2	3	4	5	6	7	8	
M.S. 1142	Zomba *Sorghum margaritiferum*, Stapf.	Sierra Leone	0·2	0·3	0·5	0·6	1·1	2·0	2·5	4·1	
„ 1445	Lugundo gundo *Sorghum elegans* (Koern), Snowden var. *elegans* (Koern), Snowden	Tanganyika	0·6	0·8	1·3	2·0	5·0	11·2	18·3	20·3	2
A.S. 3982	Kobero *S. elegans* (Koern), Snowden var. *Schumannii* (Busse et Pilger), Snowden	Tanganyika	2·0	3·0	6·0	9·0	13·1	17·2	18·6	17·0	1
M.S. 1440	Mgana *Sorghum conspicuum*, Snowden var. *usaramense* (Busse et Pilger), Snowden	Tanganyika	0·2	0·5	0·7	1·2	2·6	5·6	8·6	13·1	1
„ 1541	Sorghum No. 399 *Sorghum margaritiferum*, Stapf.	Sierra Leone	0·2	0·3	0·6	1·3	3·2	8·7	16·8	19·2	2
A.S. 1898	Talaivirichan Cholam *Sorghum Roxburghii*, Stapf. var. *hians*, Stapf.	S. India	1·3	4·8	9·3	11·5	12·6	19·6	19·0	21·9	2
„ 3947	Jebero *Sorghum conspicuum*, Snowden var. *usaramense* (Busse et Pilger), Snowden	Tanganyika	2·0	7·0	10·6	16·2	19·0	22·0	23·5	25·0	2

BLE IV.

nodal Internodal Disposition.
roup—130–170 *Days.*

nternode from bottom upwards to peduncle in cm. (Average of 10 readings)

7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
2·5	4·1	7·2	8·0	8·3	12·5	18·1	18·1	17·4	22·0	21·0	21·3	18·3	18·7	66·5
8·3	20·3	25·7	26·6	28·6	18·5	21·6	24·2	22·2	20·0	16·8	15·7	19·3	20·6	41·6
8·6	17·0	15·2	15·5	16·0	17·0	17·6	18·6	19·0	18·2	15·0	13·6	17·0	39·0	
8·6	13·1	14·5	20·0	21·4	18·7	22·7	23·5	22·4	23·6	28·5	29·4	60·3		
6·8	19·2	20·9	18·7	19·8	16·1	13·6	12·3	10·8	11·5	35·2				
9·0	21·9	22·7	23·5	22·0	25·6	26·0	29·7	60·6						
3·5	25·0	23·0	26·0	28·6	26·0	24·4	28·0	50·0						

TABLE V.

Internodal Disposition in Main Stalks and

Internodes of			Length of internode								
			1	2	3	4	5	6	7	8	9
M.S. 1142	Zomba *Sorghum margaritiferum*, Stapf.	Sierra Leone									
	Main Stalk		·3	·3	·4	·6	1·1	1·6	2·2	4·1	4·8
	Contemporary Primary Tillers	(1)	·2	·3	·5	·6	1·1	2·0	2·5	4·1	7·2
		(2)	·2	·4	·7	1·2	2·0	1·5	2·0	2·8	5·0
	Late Secondary Tillers	(1)	·3	·5	·7	1·0	6·8	13·0	13·8	15·6	21·3
		(2)	·6	·8	10·0	18·0	19·2	21·3	23·2	21·0	19·5
		(3)	·8	1·2	17·6	15·5	25·0	22·5	17·3	19·3	20·8
M.S. 3154/*d*	*Sorghum Sudanense*, Stapf.										
	Main Stalk		1·1	4·5	7·0	9·8	10·0	10·0	11·5	14·0	13·2
	Contemporary Primary Tillers	(1)	2·0	2·5	6·2	15·0	14·5	14·8	15·0	15·0	15·5
		(2)	2·0	4·7	12·6	13·5	17·2	18·3	19·5	17·6	15·6
		(3)	1·2	4·0	6·5	10·0	13·7	22·5	16·2	17·5	18·6
		(4)	2·3	3·7	11·0	14·5	16·7	15·0	14·0	12·7	14·7
	Late Secondary Tillers	(1)	2·6	6·8	12·0	12·2	16·0	20·0	22·8	24·5	50·0
		(2)	2·5	8·1	15·7	18·0	21·2	26·2	58·0		

V.

ain Stalks and Tillers.

h of internode from bottom upwards to peduncle in cm.

8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
4·1	4·8	6·6	8·2	10·0	17·8	16·9	13·7	19·3	20·2	18·7	19·1	16·0	17·8	56·6
4·1	7·2	8·5	8·3	12·5	18·1	18·1	17·4	22·0	21·0	21·3	18·3	18·7	66·5	
2·8	5·0	15·0	15·5	16·6	18·9	18·0	16·7	20·5	20·2	16·1	17·2			
15·6	21·3	28·5	25·2	20·8	17·6	25·4	66·2							
21·0	19·5	23·2	75·0											
19·3	20·8	21·3	53·0											
14·0	13·2	12·5	11·0	14·7	17·5	48·0								
15·0	15·5	15·2	14·5	15·5	46·5									
17·6	15·6	13·5	15·7	44·0										
17·5	18·6	21·2	22·0	58·5										
12·7	14·7	14·7	16·7	58·5										
24·5	50·0													

The third group comprises sorghums with the longest duration. In this group also the peduncle is longer than the longest internode. The average number of internodes is 18, there being varieties which record even 21. The internodal disposition in this group is a *bimodal* one in the distribution of their lengths. The length of the internodes rises gradually, then declines and rises slightly and declines again followed by another rise till the peduncle is reached. Internodal measurements of typical varieties in this group are given in Table IV. The three types of internodal dispositions are graphically presented in Fig. 2.

Internodes in Tillers.

Sorghum is usually tall and single stalked and thus affords excellent material for the pursuit of the internodal character. These studies, thus easily pursuable in sorghum, are therefore of wider import and assistance in similar studies on other graminaceous plants. There are also some verieties of sorghum that tiller. Sudan grass (*Sorghum Sudanense* Stapf.) is one. *Sorghum margaritiferum* Stapf., a thin-stalked grain sorghum variety from Sierra Leone, is another. The tillers in these varieties were studied for their internodal disposition. *S. margaritferum* is a very long duration variety and its main stalk is of the *bimodal* disposition type in internodal length. So also are the contemporary primary tillers. The secondary tillers growing later than the main stalk and primary tillers, have a lesser heading period and fewer number of internodes. These are *unimodal* in the disposition of their internodal length. In the wild Sudan grass which tillers freely, both the main stalk and the primary tillers almost contemporary to it, are both *unimodal* in internodal disposition. The late tillers arising from these primary tillers are however of the *uniform increasing* type. The measurements of the main stalk, contemporary primary tillers and later secondary tillers in both Sudan grass and *S. margaritiferum* are given in Table V. These measurements indicate that the trend in the evolution of internodal dispositions is from short duration *uniform increase*, to medium duration *unimodal* types, and on to the late *bimodal* ones. The individual repeats the history of the race.

Off-Season Effects.

The internodal records given above are for varieties that suit particular seasons like the rain-fed season (August to January) and summer season (March to June). The rain-fed season varieties are usually longer in duration and their growth period and internodal lengths and disposition are partly influenced by continued response to seasonal rains. In the summer season when irrigation is resorted to, the internodal disposition shows

a greater constancy in manifestation than is the case in rain-fed varieties. Summer varieties do grow in the rain-fed season but their early earheads get caught up in the rains and there is therefore poor grain setting. Rain-fed season varieties do not grow well in the summer season, their longer duration standing against their normal growth. Moreover, at flowering time the earheads get caught up in the winds of the south-west monsoon with the result that the crop is rank in growth and poor in seed setting. The growing of such rain-fed season-bound varieties like the *Peria Manjal Cholam* [*Sorghum durra* Stapf. var. *Coimbatoricum* (Burkill) Snowden] in off-seasons, ensures plenty of succulent fodder.

The effect of off-season sowing on internodal behaviour was determined on fifty plants of *Peria Manjal Cholam* sown in the month of March. The usual sowing season of this variety is early in August. The March-sown plants did not flower till October. Fifty per cent. of the plants did give earheads and these were very poor and set very little seed. The chief interest is in their internodes. With a lengthened duration (of more than 200 days till flowering), the plants were very coarse. They grew to a height of about 280 cm. The average number of internodes was 25 as against the 13 in a normal-season crop. There was a tendency (unlike the normal stalk) for the leaves to crowd towards the top of the plant. The leaves were so crowded towards the end that the plants lodged badly and developed an enormous number of stilt roots from the lower nodes. Such roots were stimulated to grow in some cases even in the tenth node above the ground level. This increased internodal number brought about by the rank growth in the off-season showed no regularity in internodal disposition. The internodal measurements in ten such abnormal plants are given in Table VI.

The Genetics of Internodal Length and Disposition.

The experience of off-season effects recorded above are a very real handicap in the pursuit of this character in inheritance. It will be evident that this character is capable of examination only when the season is fairly constant. There are therefore difficulties in the pursuit of the *steady increase* type except in the short growing season. It is practically difficult to make a cross and safely pursue the inheritance of this type of internode relatively to the other types. The only cross on record is that by Karper[4] (1932) in which a tall mutation gave simple segregations for tall and normal, tall being dominant. Karper makes no mention at all of the disposition of the internodes. Kafir is the variety handled and this is of the *unimodal* type. The gene responsible for the tallness is one that elongates individual internodes and as such Karper's experience is presumably a segregation for

TABLE VI.

The Effect of Off-Season Sowings on

Material:—A.S. 3644 *Periamanjal Chol*
var. Coimbatoricum (*Burk*

Plant No.	Length of internode from bot														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
1	2·5	6·2	10·5	16·7	14·0	16·3	20·5	21·0	13·5	10·3	10·3	9·4	7·0	8·0	
2	2·0	4·2	9·5	13·2	16·0	20·0	16·5	18·7	18·0	13·7	14·5	13·2	8·8	11·0	
3	2·0	3·8	10·3	14·0	14·7	19·0	21·0	12·0	11·5	14·0	12·8	16·9	11·0	12·3	
4	3·0	5·2	11·2	13·2	19·6	15·0	10·5	10·0	11·2	11·5	14·6	10·2	6·8	8·6	
5	3·1	8·0	14·0	15·7	17·3	16·5	21·1	14·5	12·5	11·5	10·0	8·7	10·2	8·2	
6	2·0	4·5	9·0	13·0	18·0	22·0	20·0	13·0	14·6	13·2	8·5	10·0	12·0	6·3	
7	3·5	9·0	12·3	17·0	21·3	22·5	21·5	16·0	12·0	16·2	10·0	10·2	10·0	9·0	
8	2·0	4·0	8·0	15·5	19·2	24·0	18·0	9·8	12·0	11·0	11·0	11·2	6·0	10·7	
9	3·0	6·2	12·5	15·3	23·0	19·0	12·5	14·2	12·0	9·2	11·3	13·5	7·7	10·7	
10	3·5	10·6	16·3	22·0	25·0	20·5	13·0	11·3	7·7	6·2	10·2	15·5	15·2	13·5	

TABLE VI.

The Effect of Off-Season Sowings on Internod

Material:—A.S. 3644 *Periamanjal Cholam* Sorg
var. Coimbatoricum (*Burkill*), *Snot*

Length of internode from bottom upwa								
8	9	10	11	12	13	14	15	16
21·0	13·5	10·3	10·3	9·4	7·0	8·0	9·3	3·
18·7	18·0	13·7	14·5	13·2	8·8	11·0	11·6	7·
12·0	11·5	14·0	12·8	16·9	11·0	12·3	10·3	7·
10·0	11·2	11·5	14·6	10·2	6·8	8·6	10·3	6·
14·5	12·5	11·5	10·0	8·7	10·2	8·2	16·0	13
13·0	14·6	13·2	8·5	10·0	12·0	6·3	8·0	14
16·0	12·0	16·2	10·0	10·2	10·0	9·0	8·7	13
9·8	12·0	11·0	11·0	11·2	6·0	10·7	16·0	18
14·2	12·0	9·2	11·3	13·5	7·7	10·7	16·0	16
11·3	7·7	6·2	10·2	15·5	15·2	13·5	11·2	9

VI.

s on Internodal Disposition.

Cholam Sorghum durra *Stapf.*

Burkill), *Snowden.*

n bottom upwards to peduncle in cm.

4	15	16	17	18	19	20	21	22	23	24	25	26	27	28
·0	9·3	3·7	9·0	12·3	14·0	13·5	10·3	7·5	5·6	4·5	3·5	3·2	4·5	19·6
·0	11·6	7·1	2·6	2·0	7·5	14·8	11·2	9·1	7·3	7·5	7·2	2·3		
·3	10·3	7·5	11·5	13·5	15·3	14·3	13·1	8·7	6·3	4·1	4·2	12·5		
·6	10·3	6·5	5·2	13·7	17·5	13·0	8·7	9·0	7·5	4·5	4·0	21·5		
·2	16·0	13·2	17·5	16·0	10·3	7·3	5·5	4·0	4·0	4·2	16·0			
·3	8·0	14·5	18·2	16·2	16·3	15·5	11·2	4·3	3·0	3·6	17·0			
·0	8·7	13·2	12·0	14·2	13·2	8·0	5·7	4·2	4·2	5·3	19·5			
·7	16·0	18·0	14·3	10·2	9·0	6·5	4·5	5·0	6·5	24·0				
·7	16·0	16·5	12·5	8·5	6·5	5·6	4·5	4·2	13·2					
·5	11·2	9·5	6·2	4·9	5·5	15·0								

this internodal elongation factor, the *unimodal* disposition being pure. That there is an undoubted genetic individuality both in pure lines and in inheritance for both the *unimodal* and *bimodal* types of internodes has been definitely proved in the experience recorded in the *Madras Agricultural Journal*.[5] The inheritance of the character composite 'Short-Early' and 'Tall-Late' has therein been set down to differences in internodal number and disposition in length. In the short group there are 10 internodes with a *unimodal* disposition in length. In the tall group, there are about 17 internodes showing a *bimodal* disposition in length. A factor In_1 is responsible for the production of fewer internodes with an *unimodal* disposition in length; in_1 gives rise to a greater number of internodes and a *bimodal* distribution of their lengths. In_1 is a simple dominant to in_1. This clear-cut pursuit in inheritance was made possible by both the groups being quite normal in their growth in the main rain-fed season, resulting in the character-composite 'Short-Early' and 'Tall-Late'—early and late being within the bounds of the normal growth period and season.

Thickness of the Internode.

The internodes are thickest at the base of the plant where they are congested. The average internodal diameter diminishes as it reaches the peduncle which has the smallest diameter in the plant. Within an internode, the top and bottom ends are generally thicker than the middle portion. This gives the internode a very shallow biconcave disposition. Exceptions to this condition occur in varieties with very short internodes which are heavily ensheathed. In these, the internodes may be of uniform thickness or even slightly biconcave. In rare instances, as in the case of the congested internodes of some broom-corns from New Mexico, the internodes become biconvex, and wider at the top than at the bottom. In the biconcave types with partly exposed internodes the diameter is narrowest at about the place where the sheath ceases to encircle the internode. The internodes constrict at their very base just above the point of the insertion of the leaf-sheath. The widened internode, 3–4 mm. above this constriction, is the root zone. Near this root zone the tissue is softest and in high winds there is a predisposition for the very upper nodes to snap here. The internodal length, thickness and disposition attributes detailed above are independent of the fact whether the stalks are pithy or juicy.

The Leaf-Sheath.

The leaf-sheath ensheaths the internode. It circles the internode at the base just less than $1\frac{1}{2}$ times. Measurements made in a number of plants and in a number of varieties confirm this experience of a fairly constant

1½ æstivation of the sheath. This is constant in each internode; there is a gradual decline in internodal thickness with a corresponding decline in width of sheath-base. In the *Irungu Cholam* of South India [*Sorghum Dochna* (Forsk.) var. *irungu* (Burkill) Snowden], which is a fodder variety with many tillers, fine stalks and a very long peduncle, the overlap of the leaf-sheath round the internode is slightly more than in the case of other varieties. The inner flap which is membraneous is attached to the node at a point about 5 mm. away from the axillary bud. The sheath passes over the bud only once in its twist round the stalk. In section, the sheath is thinnest at the edges and thickest about the middle which is usually against the axillary bud. The leaf-sheath twists round the internode in a clockwise or anti-clockwise direction, the one usually alternating with the other in

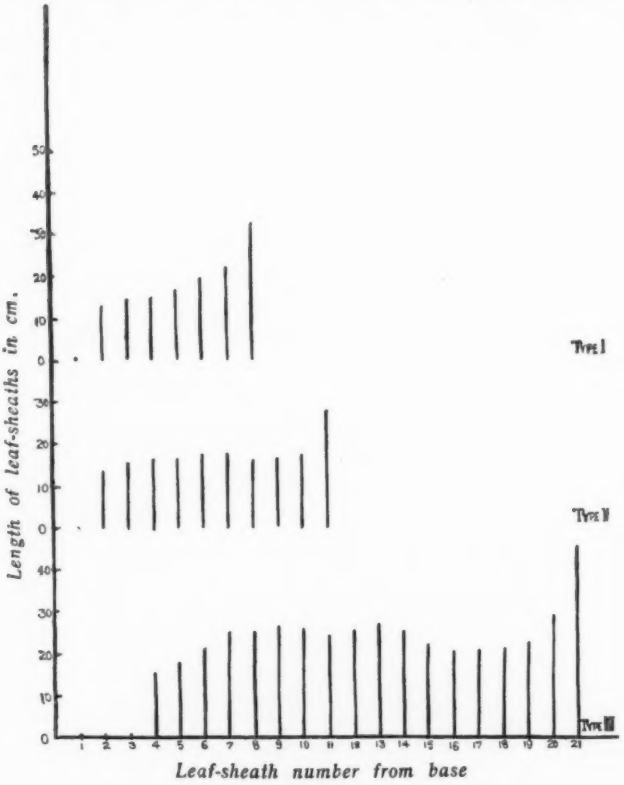

FIG. 3.

Three Types of Leaf-Sheath Dispositions.

Type I : Uniform Increase. *Type II : Unimodal.* *Type III : Bimodal.*

the plant. The leaf-sheath is widest at the base and narrows down in width towards the ligular end. This narrowing down in width is more marked in the sheath than in the internode which it enwraps with the result that towards the top, the sheath ceases to overlap well and leaves a V-shaped bit of internode exposed. In internodes with leaf-sheaths stripped off this exposed area shows out as a marked V-shaped browned-up area at the top of the internode.

The length of the leaf-sheath shows a disposition to run roughly parallel to the disposition of the length of the internode. For the *uniform increase, unimodal* and *bimodal* dispositions of leaf-sheath, Tables VII, VIII and IX provide data. These three types are illustrated in Fig. 3. Fig. 4 graphically represents the parallelism between internodal and leaf-sheath dispositions.

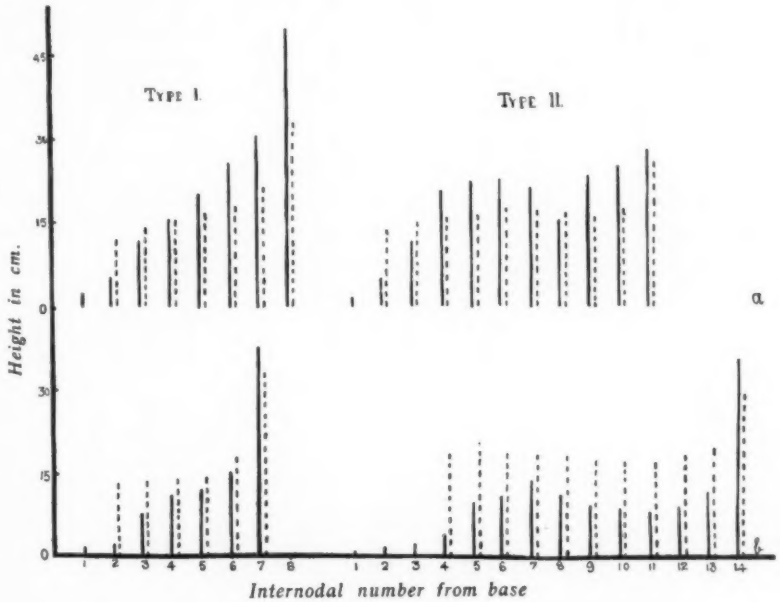

FIG. 4.

Leaf-Sheaths (dotted lines) and Internodes.
a-Exposed Nodes. *b*-Enclosed Nodes.

Conner and Karper[6] by varying the time of sowing, noted that the leaf-sheath was less susceptible to change in length than the internode. They therefore concluded that the ensheathed internode was not a reliable guide for descriptive botanical literature. From the above studies it will be

TABLE VII.

Leaf-Sheath Type 1—*Steady Leaf-Sheath Increase.*

Early Duration Group—80–100 *Days.*

Selection No.	Name of Variety		Length of internode from bottom upwards to penduncle in cm. (Average of 10 readings)									
			1	2	3	4	5	6	7	8	9	10
A.S. 1751	Feterita *Sorghum caudatum*, Stapf. var. *Feterita*, Stapf.	China	..	13·5	14·0	15·6	17·8	18·0	18·5	19·5	22·0	32·0
„ 3460	Feterita *S. caudatum*, Stapf. var. *Feterita*, Stapf.	Texas	..	..	..	14·2	15·0	16·0	17·5	18·4	19·2	30·0
„ 1745	Feterita *S. caudatum*, Stapf. var. *Feterita*, Stapf.	Texas	..	..	10·5	12·2	13·5	14·0	14·5	16·0	28·0	
„ 578	Pedda Jonna (Edakula Jonna) *Sorghum durra*, Stapf.	S. India	..	12·5	13·8	15·4	16·2	18·5	22·0	32·7		
„ 2876	Dawn Kafir *Sorghum caffrorum*, Beauv. var. *albidum* (Koern), Snowden	China	..	..	16·5	18·0	19·6	19·7	19·9	35·5		
M.S. 3076	Elton Sorgo Near *Sorghum dochna* (Forsk.), Snowden	Texas	..	13·0	13·2	14·0	14·5	17·5	32·0			
„ 3102	Early Kalo Near *S. caffrorum*, Beauv.	Kansas	..	13·5	14·2	14·5	15·6	16·8	27·5			

TABLE VIII.

Leaf-Sheath Type 2—Unimodal Leaf-Sheath D
Medium Duration Group—100–130 *D*

Selection No.	Name of Variety		Length of leaf-sheath from bott					
			1	2	3	4	5	6
M.S. 2133	Blackhull Kafir *Sorghum caffrorum*, Beauv. var. *albofuscum* (Koern), Snowden	Texas	..	..	19·5	20·6	21·5	24·0
„ 1495	Kampupu *Sorghum nigricans* (Ruizetpavan) var. *cerevisiæ* (Stapf.), Snowden	N. Rhodesia	..	..	..	..	8·5	16·5
„ 2379	Sunrise Kafir *Sorghum caffrorum*, Beauv. var. *albofuscum* (Koern), Snowden	Texas	..	..	16·2	17·5	18·6	19·2
„ 2395	White yolo *Sorghum caffrorum*, Beauv. var. *albofuscum* (Koern), Snowden	Texas	..	..	..	17·8	18·5	18·8
„ 1456	Masaba *Sorghum guineense*, Stapf. var. *involutum*, Stapf.	Nigeria (from Kew)	..	..	15·5	16·0	16·5	20·0
A.S. 60	Peria Manjal Cholam *Sorghum durra*, Stapf. var. *Coimbatoricum* (Burkill), Snowden	Somayanur, S. India	..	16·0	17·8	18·0	19·8	20·1
„ 477	Nar Cholam Koilpatti, Tinnevelly District, S. India *Sorghum dochna* (Forsk.), Snowden var. *irungu* (Burkill), Snowden		14·8	15·6	16·1	15·2	14·7	13·5
„ 1543	Vellai Cholam (Strain) *Sorghum subglabrescens*, Schweinf et Aschers var. *irungiforme* (Burkill), Snowden	S. India	..	..	16·5	19·7	21·2	19·5
M.S. 3154/*d*	Sudan Grass *Sorghum sudanense*, Stapf.	S. India	..	..	..	20·5	22·0	21·8
A.S. 809	Chinna Manjal Cholam *Sorghum subglabrescens*, Schweinf et Aschers var. *compactum* (Burkill), Snowden	Coimbatore, S. India	..	13·5	15·0	15·7	16·0	17·0
„ 3700	Broom corn *Sorghum dochna* (Forsk.), Snowden var. *technicum*, Snowden	Bihar and Oriass	..	17·6	19·2	22·4	24·2	23·0

TABLE VIII.

Leaf-Sheath Type 2—Unimodal Leaf-Sheath Disposition.
Medium Duration Group—100–130 *Days.*

	Length of leaf-sheath from bottom upwards							
	1	2	3	4	5	6	7	8
Texas	..	..	19·5	20·6	21·5	24·0	24·6	22·4
. Rhodesia	..	..	..	..	8·5	16·5	17·7	19·6
Texas	..	..	16·2	17·5	18·6	19·2	19·4	17·6
Texas	..	..	..	17·8	18·5	18·8	18·2	18·2
rom Kew)	..	..	15·5	16·0	16·5	20·0	16·1	19·5
S. India	..	16·0	17·8	18·0	19·8	20·1	19·3	18·4
, S. India	14·8	15·6	16·1	15·2	14·7	13·5	12·6	12·1
S. India ers	..	..	16·5	19·7	21·2	19·5	19·0	15·6
S. India	..	..	..	20·5	22·0	21·8	22·0	20·6
, S. India ers	..	13·5	15·0	15·7	16·0	17·0	17·2	16·6
nd Oriass	..	17·6	19·2	22·4	24·2	23·0	23·7	27·6

Disposition.
Days.

ottom upwards to flag-sheath in cm. (Average of 10 readings)

	7	8	9	10	11	12	13	14	15	16
0	24·6	22·4	22·6	21·6	20·8	20·8	21·5	22·0	22·6	35·0
5	17·7	19·6	19·0	18·4	16·4	16·7	15·4	18·6	29·5	
2	19·4	17·6	17·0	17·4	13·6	15·5	18·3	28·4		
8	18·2	18·2	16·9	16·2	16·4	17·2	19·6	28·6		
0	16·1	19·5	19·8	20·2	22·2	27·5	31·4	47·6		
1	19·3	18·4	18·7	18·7	18·7	23·5	34·9			
5	12·6	12·1	12·0	12·0	12·3	16·8	32·9			
5	19·0	15·0	14·9	15·6	18·0	26·0				
8	22·0	20·0	18·5	18·2	19·3	37·0				
0	17·2	16·0	15·8	16·8	26·0					
0	23·7	27·0	31·5	45·7						

TABLE

Leaf-Sheath Type 3—Bimodal
Late Duration Group

Selection No.	Name of Variety		Length of leaf-shea						
			1	2	3	4	5	6	
M.S. 1142	Zomba *Sorghum margaritiferum*, Stapf.	Sierra Leone	..	..	..	14·0	14·5	15·0	
„ 1445	Lugundo gundo *Sorghum elegans* (Koern), Snowden var. *elegans* (Koern)	Tanganiyka	..	..	..	15·3	17·6	20·5	
A.S. 3982	Kobero *Sorghum elegans* (Koern), Snowden var. *Schumannii* (Busse et Pilger), Snowden	Tanganiyka	..	..	..	20·0	20·0	21·0	
M.S. 1440	Mgana *Sorghum conspicuum*, Snowden var. *usaramense* (Busse et Pilger), Snowden	Tanganyika	..	..	..	17·5	20·5	22·6	
„ 1541	*Sorghum* No. 399 *Sorghum margaritiferum*, Stapf.	Sierra Leone	..	..	..	17·5	19·5	20·5	
A.S. 1898	Talaivirichan Cholam *Sorghum Roxburghii*, Stapf. var. *hians*, Stapf.	S. India	..	15·8	16·0	17·5	22·5	21·0	
„ 3947	Jebero Rufigi *Sorghum conspicuum*, Snowden var. *usaramense* (Busse et Pilger), Snowden	Tanganyika	..	..	17·5	19·0	21·0	22·0	

TABLE IX.

Leaf-Sheath Type 3—Bimodal Leaf-Sheath Disposition.
Late Duration Group—130–170 *Days.*

	Length of leaf-sheath from bottom upwards to fl										
	1	2	3	4	5	6	7	8	9	10	
e	..	..	..	14·0	14·5	15·0	15·2	16·6	17·8	18·1	19
a	..	..	..	15·3	17·6	20·5	24·5	24·5	26·0	25·7	24
a	..	..	..	20·0	20·0	21·0	22·0	23·0	22·0	22·0	22
a	..	..	..	17·5	20·5	22·6	24·5	24·8	24·1	23·8	23
r	..	..	..	17·5	19·5	20·5	21·5	20·4	22·5	23·9	22
a	..	15·8	16·0	17·5	22·5	21·0	20·5	19·5	21·0	22·5	23
a	..	..	17·5	19·0	21·0	22·0	21·0	22·0	21·0	20·0	2

Disposition.
ays.

n upwards to flag-sheath in cm. (Average of 10 readings)

9	10	11	12	13	14	15	16	17	18	19	20	21
7·8	18·1	19·2	19·4	18·8	14·8	16·8	22·7	23·3	18·4	20·5	27·8	45·5
6·0	25·7	24·3	25·0	26·5	24·5	21·8	20·0	20·2	20·5	22·2	28·2	45·0
2·0	22·0	22·0	22·0	19·0	20·0	21·0	20·0	20·0	20·0	25·0	36·0	
4·1	23·8	23·0	21·3	22·9	33·0	22·2	22·8	24·5	28·1	49·8		
2·5	23·9	22·0	21·5	19·2	18·3	18·5	24·3	35·2				
1·0	22·5	23·6	18·6	17·8	24·5	49·5						
1·0	20·0	20·0	20·0	23·0	32·0	50·0						

noticed that there are definite internodal-length and sheath-length groups in sorghum and that in the distribution of its length, the sheath follows a trend similar to that of the internode. It will be seen from the following table that internodes vary within wide limits in their lengths and that leaf-sheaths vary within lesser limits. The total length of leaf-sheaths and internodes for a few typical varieties of sorghum are given below:—

Variation in the Total Lengths of Leaf-Sheath and Internode.

(*Varieties with* 12–15 *internodes.*)

Selection No.	Name of Variety		Total length from top excluding flag and peduncle (Average of 10 typical plants)	
			9 Internodes cm.	9 Leaf-sheaths cm.
M.S. 2133	Blackhull Kafir *Sorghum caffrorum*, Beauv. var. *albofuscum* (Koern), Snowden	Texas	68·0	198·9
„ 2395	White yolo *S. caffrorum*, Beauv. var. *albofuscum* (Koern), Snowden	Texas	89·4	160·0
„ 2379	Sunrise Kafir *S. caffrorum*, Beauv. var. *albofuscum* (Koern), Snowden	Texas	119·7	158·6
„ 3154/*d*	Sudan Grass *S. sudanense*, Stapf.	S. India	130·0	177·8
A.S. 809	Chinna Manjal Cholam *S. subglabrescens* var. *compactum* (Burkill), Snowden	S. India	174·2	143·0
M.S. 1456	' Masaba ' *S. guineense*, Stapf. var. *involutum*, Stapf.	Nigeria	203·3	195·2
A.S. 1543	Vellai Cholam *S. subglabrescens* var. *irungiforme* (Burkill), Snowden	S. India	209·1	159·4
„ 1093	Talaivirichan Cholam *S. Roxburghii*, Stapf. var. *hians*	S. India	120·0	189·0
„ 60	Peria Manjal Cholam *S. durra*, Stapf. var. *Coimbatoricum* (Burkill), Snowden	S. India	233·2	175·2
	Range in total Internodal length 68·0—233·2 cm. „ Leaf-sheath length 143·0—198·9 cm.			

The result of the above condition is that certain varieties are heavily ensheathed leaving practically no internodes exposed. This brings the leaves closer together and imparts a characteristic look to the plant, so that certain varieties like Kafir stand well marked out for this much ensheathed and close-leaved character.

The Axillary Bud.

There is a bud in the axil of every leaf. This is usually absent in the axil of the boot—the sheath of the flag. In varieties in which the leaf-sheath covers only a portion of the internode the buds are usually prominent at every internode and could be stimulated into activity with the prevalence of the necessary conditions. In heavily ensheathed American varieties where, in the lower internodes, there is a tendency for one sheath to be above another sheath, the lower axillary buds that are thus smothered tend to be less prominent than the buds in the axils of the leaf-sheaths higher up. When the crop is ripe, should there be a downpour of rain the top buds are those that are easily stimulated to sprout. The effect of the intactness of the leaf-sheath on the stimulation of adventitious roots from the root zone has already been recorded.[7] The shape of the bud is the shape of the prophyll, the first leaf of the axillary shoot. This prophyll is prominently bi-keeled and effectively embraces and protects the tender growing point of the bud. It is generally elliptic in shape with a broad base.

The bud is situated just above the node in the constricted area below the root zone. Sunk into the internodal tissue as it is, it makes a depression, which is prolonged into a groove that runs up the internode. The length and prominence of this groove is determined by the size of the bud and the internodal length. Being usually budless the penducle has no such groove.

The Bloom Band.

The bloom band is that part of the internode which is at the very top of the internode and immediately below the node. It is called the bloom band for the reason that it is in this area that the bloom[8] manifests itself at its best. This band is finely grooved and is the toughest portion in the internode, in marked contrast to the other extremity which is the softest. When exposed, this band tends to brown up.

Nodal Band.

There is a band of soft tissue just above the node, at the extreme base of the leaf-sheath. It could be likened to a pulvinus. This nodal band[9] is markedly seen on the plant in varieties in which the internodes are exposed. Situated as it is between the light green colour of the leaf-sheath above and

TABLE X.

Width of Nodal Band in mm. (Average of 10 readings pe

Selection No.	Name of Variety		Flag	2	3	4	5	6	7
A.S. 269	Hagari Red Near *Sorghum durra*, Stapf.	S. India	1·7	1·9	2·1	2·4	2·6	2·7	2·7
T_{12}	Tella Jonna *Sorghum cernuum*, Host var. *globosum* (Hack), Snowden	Bellary, South India	1·8	2·1	2·3	2·8	2·9	3·0	3·3
A.S. 577	Kaka Cholam *Sorghum Roxburghii*, Stapf. var. *hians*, Stapf.	Dharmapuri, S. India	1·4	1·7	1·9	2·1	2·3	2·6	2·7
M.S. 1141	Tayila *Sorghum margaritiferum*, Stapf.	Sierra Leone	2·5	2·7	2·9	2·8	3·0	2·8	2·7
A.S. 1374	Peria Manjal Cholam *Sorghum durra*, Stapf. var. *Coimbatoricum* (Burkill), Snowden	S. India	2·0	2·0	2·2	2·5	2·6	2·8	3·3
„ 198	Sen Cholam *Sorghum subglabrescens* var. *rubidum* (Burkill), Snowden	S. India	2·2	2·5	2·5	2·5	2·8	3·0	3·2
M.S. 3000	Klerksdorp *Sorghum caffrorum*, Beauv.	S. Africa	1·5	1·5	1·6	1·6	1·6	1·7	1·9
„ 3469	Blackhull Kafir *Sorghum caffrorum*, Beauv. var. *albofuscum* (Koern), Snowden	Australia	1·5	1·7	1·6	1·5	1·6	1·8	1·9
A.S. 1543	Vellai Cholam *Sorghum subglabrescens*, Schweinf et Aschers var. *irungiforme* (Burkill), Snowden	S. India	2·5	3·0	3·1	3·2	3·2	3·8	4·6
„ 1425	Irungu Cholam *Sorghum dochna* (Forsk.), Snowden var. *irungu* (Burkill), Snowden	S. India	1·5	1·7	1·9	2·1	2·5	2·8	3·1
M.S. 3386	White Kafir *Sorghum caffrorum*, Beauv.	S. Africa	1·6	1·9	2·4	2·4	2·6	2·6	2·6
A.S. 4489	Pura Vellai *Sorghum subglabrescens*, Schweinf et Aschers var. *irungiforme* (Burkill), Snowden	S. India	2·9	3·6	3·9	4·6	4·4	4·3	3·9
M.S. 3307	Dwarf Broom Corn *Sorghum dochna* (Forsk), Snowden var. *technicum*, Snowden	U.S.S.R.	2·0	2·6	2·8	2·5	2·4	2·4	2·5
A.S. 4425	Feterita *Sorghum caudatum*, Stapf. var. *Feterita*, Stapf.	Sudan	2·8	3·3	3·1	2·9	3·1	3·0	
M.S. 3303	Two Foot Milo *Sorghum subglabrescens*	New Mexico	1·8	2·0	2·0	2·0	2·1	2·2	

TABLE X.

Width of Nodal Band in mm. (Average of 1

ariety	Flag	2	3	4	5
S. India	1·7	1·9	2·1	2·4	2·6
Bellary, South India	1·8	2·1	2·3	2·8	2·9
en Dharmapuri, S. India	1·4	1·7	1·9	2·1	2·3
Sierra Leone	2·5	2·7	2·9	2·8	3·0
f. S. India	2·0	2·0	2·2	2·5	2·6
, Snowden					
S. India	2·2	2·5	2·5	2·5	2·8
den					
S. Africa	1·5	1·5	1·6	1·6	1·6
Australia	1·5	1·7	1·6	1·5	1·6
owden					
S. India	2·5	3·0	3·1	3·2	3·2
einf et Aschers owden					
S. India	1·5	1·7	1·9	2·1	2·5
owden n					
S. Africa	1·6	1·9	2·4	2·4	2·6
S. India	2·9	3·6	3·9	4·6	4·4
einf et Aschers owden					
U.S.S.R.	2·0	2·6	2·8	2·5	2·4
owden					
Sudan	2·8	3·3	3·1	2·9	3·1
New Mexico	1·8	2·0	2·0	2·0	2·1

LE X.

(*Average of* 10 *readings per Node.*)

3	4	5	6	7	8	9	10	11	12	13	14	15	16 Ground-level
·1	2·4	2·6	2·7	2·7	2·7	2·8	2·8	3·0	3·5	3·7	3·8	4·3	5·0
·3	2·8	2·9	3·0	3·3	3·3	3·7	3·8	3·7	3·9	4·5	5·0		
·9	2·1	2·3	2·6	2·7	3·1	3·1	3·4	3·3	3·8	3·5			
·9	2·8	3·0	2·8	2·7	2·8	3·0	3·0	3·1	3·2				
·2	2·5	2·6	2·8	3·3	3·2	3·5	3·7	4·0					
·5	2·5	2·8	3·0	3·2	3·5	3·8	3·5						
·6	1·6	1·6	1·7	1·9	2·1	2·0	2·5						
·6	1·5	1·6	1·8	1·9	1·8	2·0							
·1	3·2	3·2	3·8	4·6	4·6								
·9	2·1	2·5	2·8	3·1	3·0								
·4	2·4	2·6	2·6	2·6	2·6								
·9	4·6	4·4	4·3	3·9									
·8	2·5	2·4	2·4	2·5									
·1	2·9	3·1	3·0										
·0	2·0	2·1	2·2										

the yellowish green of the exposed internode below, this nodal band is very prominent at the flowering stages of a crop. In dry leaves the connection between the nodal band and the leaf-sheath snaps easily. Any attempt to peal off the band removes a bit of tissue from the bloom band immediately below it. When the sheath axils are coloured purple, the purple colour is confined to the very base of the leaf-sheath proper and does not extend further down to the inner side of this nodal band. In red-grained varieties, this nodal band is green when fresh, but when dry, takes on a reddish colour, which leaves on the dry stalks dark bands about each node. In the fresh state this nodal band could be green, purple or light purple. In brown-grained varieties the nodal band may be light purple or green, but is never purple. When there is no brown wash on the grain and in consequence the anthers are sienna in colour, the nodal band shows the best manifestation of purple. The bands are then cracked in appearance. When the root primordia are stimulated into growth they easily pierce through the base of the sheath, just above the nodal band.

The width of the nodal band shows a slight variation in varieties. Table X gives the width of the nodal band within the plant and in typical varieties. The width of individual bands ranges from 1·4 to 5 mm. Veriet-al averages range from 1·7 to 3·9 mm. The band is very narrow in kafir (1·7 mm.). It is widest (3·9 mm.) in *Pura Vellai*, a variety of *S. subglabrescens*. Within a plant it could be said generally that the nodal band shows a tendency to become less wide at the upper nodes. Individual nodal bands in the lower portions of a plant may occasionally be as wide as 5 mm. At the node from which the peduncles arise it is narrowest. This specialised cushiony tissue is of great value to the plant, for when plants happen to fall down and endeavour to bend up at a node, the upper band adapts itself very nicely to strengthen the elbow-like growth by length-ening below and shrinking above.

Summary.

In sorghum, the longer the duration of the variety the taller the plant tends to be. In duration, sorghums fall into three broad groups :—(1) Early, (2) Medium and (3) Late. The number of internodes increases with the duration. In group (1) there is a *steady increase* in internodal length, the peduncle being always markedly long. In group (2) the internodes are *unimodal* in disposition, rising, slightly falling and then again rising up to the peduncle. Group (3) is *bimodal* with a double rise and fall ending with the final rise towards the peduncle. The length of the leaf-sheath also follows these three systems of disposition, though in a less graphic measure. These

internodal numbers and dispositions being season-conditioned are at their best constancy and individuality in their respective seasons. In inheritance, Short-Early plants of the *unimodal* disposition have proved a sharp and simple dominant to the *bimodal* Tall-Late group of plants. The tillers in each group that have a shorter growing period and a fewer number of internodes show an internodal disposition of the group, lower than the main stalk group. The individual repeats the history of the race.

Minute morphological descriptions of the internode, the leaf-sheath, the axillary bud, the bloom band and the nodal band are given.

REFERENCES.

1. Rangaswami Ayyangar, G. N. .. *Madras Agric. Jour.*, 1935, **23**, 350–52.
2. ————, *et al.* .. .. *Ibid.*, 1936, **24**, 247–48.
3. Sieglinger, J. B. .. .. .. *American Soc. Agron.*, 1936, **28**, 636–42.
4. Karper, R. E. .. .. .. *American Nat.*, 1932, **66**, 511–29.
5. Rangaswami Ayyangar, G.N., *et al.* *Madras Agric. Jour.*, 1937, **25**, 107–18.
6. Conner, A. B., and Karper, R. E. .. *Science*, 1917, **45**, 144–45.
7. Rangaswami Ayyangar, G. N. and Rao, V. P. .. .. *Curr. Sci.*, 1935, **3**, 485–86.
8. ————, *et al.* .. .. *Proc. Ind. Acad. Sci.*, 1937, **5**, 4–15.
9. ———— .. .. .. *Madras Agric. Jour.*, 1934, **22**, 1–11.
10. ————, *et al.* .. .. *Ind. Jour. Agric. Sci.*, 1934, **4**, 81-89.

ON A FLAGELLATE OF THE INTESTINE OF *TATERA INDICA* HARDWICKE.

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and
Dattá Loundó.
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Received March 22, 1938.

In the intestine of the field rat *Tatera indica* Hardwicke, caught at Nova Góa and kindly identified by Dr. Baini Prashad from Calcutta, we have found a curious flagellate whose morphology and life-cycle will constitute the object of this note.

Actively motile, having an oval, rarely a pyriform appearance, this flagellate shows after vital staining an alveolar constitution, with a strongly refringent nucleus, situated near the anterior pole.

Some forms are rather roundish and devoid of motility. They could be interpreted as cysts, but some of them show the same movements as the elongated individuals. A sharp distinction between these roundish motile and non-motile forms is not possible, as by vital or post-vital stains the flagella are not easy to be detected. Important it is to note that the parasite does not possess any axostyle or undulant membrane.

The best idea of its structure could be made in slides prepared by wet fixation through sublimate alcohol or Bouin and stained by Hemalun of Mayer and specially by iron hæmatoxylin (differentiation by chlohydric alcohol at 0·5 per cent., controlled under the microscope).

The parasite has an elongated, or oval, rarely pyriform or roundish form. Its membrane is of periplastic nature and its internal constitution strongly alveolar, with large roundish alveoles, containing bacteria, and some of them, specially those near the nucleus, more strongly stained than the others. This alveolar protoplasm often fills completely the internal surface of the body, reaching till the line of the periplast; but sometimes is rather contracted in order that between this alveolar layer and the periplast remains a clear hyaline zone, which in roundish forms, when the flagella do not exist or are difficult to be detected, may give the idea that we are dealing with a large amœba.

The nucleus is round and in quiescent stage, of protokaryon type. It is situated near the anterior pole of the parasite. Attached to the anterior part of its membrane lies the basal apparatus, constituted by two conspicuous granules, sometimes very close to one another, sometimes united by a distinct fibril. From one of these granules start two flagella of the same length, very thin and difficult to be detected, and which, after a small intracytoplasmic traject become external and guide the movement of the parasite. Both flagella are of the same size and have the same function, none of them being recurrent or acting as gubernaculum, none of them showing any other formation such as trace of membrane, etc., attached to them, belonging thus to a pure monadic type. The second granule gives origin to a parabasal, which, however staining less intensely than the nucleus, is very distinct and sometimes embraces the nucleus to a certain extent, sometimes progresses further in the cytoplasm taking different forms. Its constitution seems rather compact, but in some specimens stained by Hemalun of Mayer, we have seen a striped appearance depicted in our Fig. A, 3.

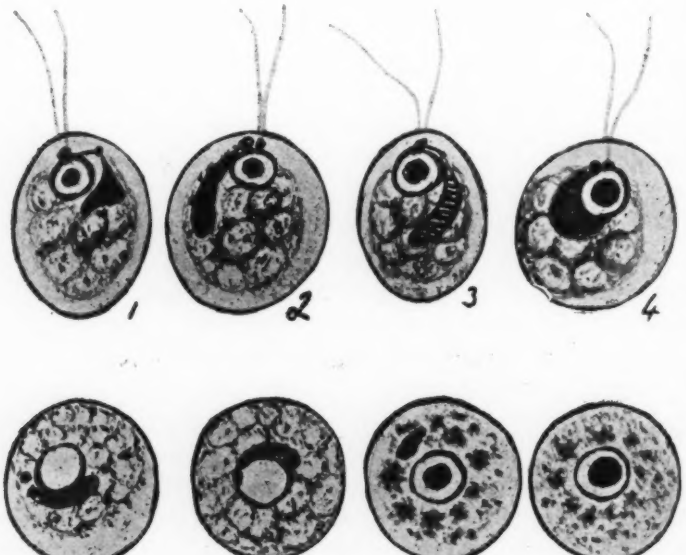

Fig. A.

In divisional phenomena the nuclear contents suffer the following modifications. A centriole is formed (Fig. B, 2) which divides itself into

two daughter centrioles united by a desmose (Fig. B, 3). The whole endosome is now reduced to a kind of chromatic dust from which emerge three groups of chromosomes whose final number is six (Fig. B, 5–10). Equatorial plate, anaphasis and telophasis follow (Fig. B, 11–13). We have not seen definite cytodieresis and splitting of a mother-cell into two individuals, non-obstant having examined in detail hundreds of this flagellates.

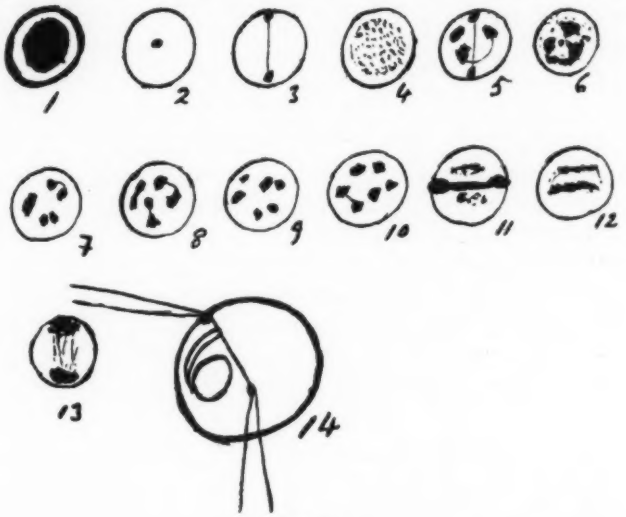

Fig. B.

Fig. B, 14 is very interesting: it shows the division of the flagellar apparatus. The blepharoplast is divided and the daughter blepharoplasts are connected by a basodesmose. The nucleus in this individual was in quiescent phase.

We have not been fortunate enough to see how the division of the parabasal occurs.

* * *

As we have incidentally referred, it was very difficult to decide whether the roundish forms seen in fixed slides were cysts or not on account of the difficulty in detecting the flagella. It seems that the flagellate passes through a precystic stage, where it looses the flagella, keeping however the alveolar constitution of the endoplasm and the basal granules, which in a further stage fuse together appearing as a single body, closely attached to the nuclear membrane. Later on, the alveoles disappear and are substituted by some irregular masses of a weakly staining substance scattered in the whole

protoplasm (Fig. A, 7). The parabasal is now separated from the nucleus and finally reabsorbed and in interior of the parasite remains only a karyosomic nucleus, which has gradually come from its lateral to a central position.

* * *

Classification.—In resumé, we are in the presence of a flagellate belonging to the order *Protomonadina*, family *Monadidæ*. Surrounded by a periplast, it has an alveolar protoplasm, an anterior nucleus and two blepharoplasts, one giving origin to two anterior monadic flagella, another to a parabasal. In cystic stages the nucleus comes to the centre and the accessory structures are reabsorbed. The divisional phenomena are of mitotic nature.

We do not find in the protozoological literature any flagellate of this kind. A very closely allied form was classified by Alexieff in the genus *Tetramastix* 1909. We will take from the *Lehrbuch der Protozoenkunde* of Doflein the characteristics of the genus: Parasitische flagellaten mit vier Geisseln am Vorderende, die gemeinsam von vorn nach hinten Schlagen Wie bei *Tetramitus* ist kein Achsenstaf vorhanden. Zum Unterschied von *Tetramitus* fehlt ein Cytostom; die Ernahrung erfolgt durch gelöste Stoffe. Neben den Kern liegt ein stark ausgebildeter Parabasalkorper. In Enddarm von Amphibien.

In this genus Alexieff classified the *T. bufonis* (Dobell), syn. *Monocercomonas bufonis* Dobell, as this parasite does not possess any axostyle which is always present in the genus *Monocercomonas* Grassi 1879. *Tetramastix Swezyi* was described by Grassé in American amphibians.

Our parasite cannot belong to the genus *Heteromita* Dujardin as this includes small, strongly ameboid flagellates with two flagella of unequal size, the shorter, which may be thicker than the other, having once or twice the length of the body, and the finer and longer two to four times the same length. It does not possess, moreover, any parabasal.

Among the free living Monadids Nägler described his *Monas gelatinosa*, whose structure has some resemblance with our parasite and makes this flagellate quite different from all other species of *Monas* hitherto recorded. Pascher and Lemmermann[1] give for this protozoon the following characters: Zellen kugelig oder etwas oval mit dünner Gallerthülle, ca 10 mikron gross, freischwimmend, oder festsitzend. An Stelle der Mundstriches eine nur in fixierten Zustande sichtbare "Basalplatte" vorhanden, der ein Basalkorn vorgelagert ist. Augenfleck fehlt. Hauptgeissel 1/2 bis Korperlang, Nebengeissel Zuweilen verdoppelt oder auch ganz fehlend. 1 kontraktile vacuole meist in der vorderende. Deuerzellen nicht bekannt. The figure 247 *b* of the

authors is strongly suggestive of the similarity of the internal structure between *Mona gelatinosa* Nägler and the parasite we are describing now.

As we have said above, the existence of the parabasal which does not constitute a character of the genus *Monas* does not in our opinion allow the inclusion of the species of Nägler in this genus.

As the genus *Tetramastix* Alexieff possesses four flagella, the more appropriate term for our parasite would be *Diplomastix*. Unhappily this designation is preoccupied, as it was used by Kent (1881) for *Bodo caudatus* Duj. (1811) (Syn. *Diplomastix caudata* Kent). The same designation was employed by Möbius for a Cryptobiid found by Dahl in 1887 in the intestine of the marine fish *Cyclopterus lumpus*. The name given by Möbius was *Diplomastix dahlii*, 1888 (= *Cryptobia dahlii*).

So we will name our parasite *Dimastigomastix lateræ* n.gen., n.sp.

Measurements of the Parasite.—Elongated forms 16 to 28 microns long, 12 to 20 microns broad; circular forms and cysts 16 to 20 microns; nucleus 4 to 6 microns, flagella nearly the same length as the body.

Summary.—*Dimastigomastix lateræ* n.gen., n.sp. oval or roundish flagellate, strongly alveolar protoplasm, 16–28 microns over 12–20, nucleus on anterior pole and to which are attached two basal granules, often united by a fibril, giving origin the one to two anterior, equal sized flagella, the other to a distinct parabasal. Division by mitosis with six chromosomes. Encystment with reabsorption of the organels, and central position of the nucleus. Parasite of the intestine of *Tatera indica* Hardwicke caught in the rice-fields surrounding Nova-Gôa.

BIBLIOGRAPHY.

[1] Pascher, A., und Lemmermann, E., *Die Susswasserflora Deutschlands, Osterreichs und der Schweiz herausgegeben* von A. Pascher, Heft 1, Flagellatæ 1, Jena 1914.

STUDIES ON *PEACHIA* FROM MADRAS.

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Received February 4, 1938.
(Communicated by Professor R. Gopala Aiyar, Madras.)

PART I.

On A New Species of *Peachia* from Madras.*

Introduction.

Species of the Actinian genus *Peachia* have been described from different parts of the world, but almost all the known species are from Temperate zones. Perhaps, the only previous record of the genus from the Tropics is that of K. R. Menon (1927) who noted its occurrence in the littoral fauna of the Krusadi Islands. Specific identity of this anemone was not, however, determined by Menon, though its distinguishing external features were noted in his description. The occurrence of the adult forms as well as the characteristic medusophilous larvæ of *Peachia* on the Madras coast will be of considerable interest in view of our ignorance of the anemone fauna of the Bay of Bengal. A single specimen belonging to this genus was dredged off the Madras coast from about a depth of not more than six fathoms, in July 1935. I have compared the anemone with Menon's species with which it is identical in all essential features. Since the anemone shows unmistakable differences from all the other known species of *Peachia*, it is here described as a new species, for which the name *Peachia tropica* is suggested.

Sub-Tribe ABASILARIA (*Athenaria*), Carlgren.

Family Ilyanthidæ, Gosse.
(As redefined by Stephenson, 1935.)

Genus Peachia, Gosse.

Peachia tropica Spec. Nov.
(*Peachia* sp. Menon, 1927.)

Diagnosis.—Column long and vermiform, the differentiation into regions being indistinct. Tentacles, 16, with an inner smaller and an outer larger set of tentacles. Mesenteries disposed in eight pairs, consisting of a first cycle of six, and a second cycle of two. The mesenteries of the first cycle

* Abstract of the paper was published in *Proc. Ind. Sci. Cong.*, 1937 (Hyderabad), *Zool. Abst.* 7.

and the second cycle almost similar. Conchula with five lobes in the adult condition.

Nematocysts of the tentacles	..	.. 10-14 × 2-3·5 μ
Nematocysts of the column	..	.. 8-15 × 2-3·0 μ
Spirocysts of the tentacles	..	.. 9-16 × 2-4·0 μ

External Characters.

The anemone is long and vermiform, about 30 mm. long and 9 mm. wide at the broadest part in the expanded condition. The column is whitish-yellow in colour, with splashes of reddish-brown markings at the bases of the tentacles. The markings on the tentacles together form a joint pattern as in *Peachia hastata* (Stephenson, 1928). Each tentacle is usually

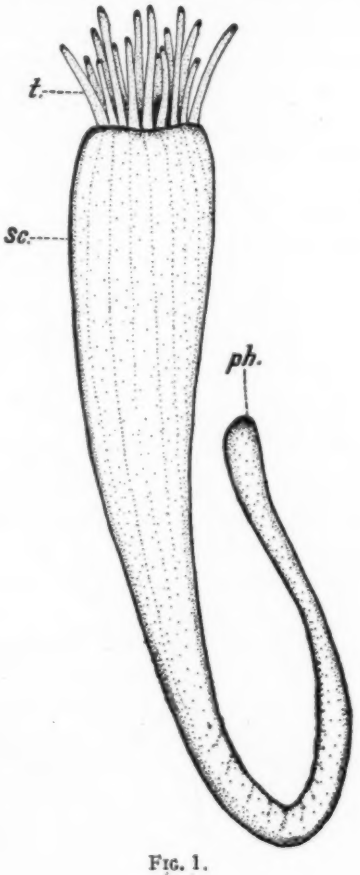


Fig. 1.

barred four times, each bar consisting of a pair of marks. In addition to this, the tentacles bear dark spots at their extremities.

Column and Physa.—The body of the anemone shows little differentiation into special regions. The physa is hardly distinct from the rest of the column and does not present morphological peculiarities. The column is not divided into a scapus and capitulum; but its broader part is the distal half which corresponds to the scapus. The column-wall is thin and reveals the insertions of the mesenteries, of which sixteen could be counted. Stinging warts, cinclides, or distinct groups of nematocysts are not found on the column. The few nematocysts that occur are of a small size and have a scattered arrangement.

K. R. Menon (1927) has observed that the body is covered by numerous minute suckers with which the animal attaches to the bottom of glass vessels. I have not found any real sucker on the column, but a number of minute papillæ are found in the living anemone, with which attachment to foreign bodies may be effected. These are mere cell accumulations containing more supporting cells than in other regions, as suggested by Carlgren (1921) for the European species *Peachia hastata* in which Haddon and Dixon (1885) observed 'minute suckers'. The structures referred to by Menon for the Krusadi anemone, and by Haddon and Dixon for *P. hastata*

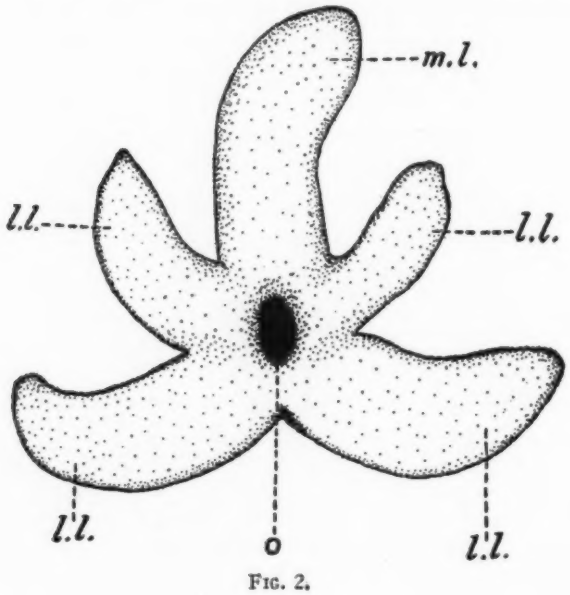


Fig. 2.

appear to be identical; they cannot be considered as true suckers, or even as 'Halcampa papillæ'.

The Oral Disc and the Conchula.—The disc is 4–6 mm. wide; it is thin and depressed without indications of lobulation or markings, excepting the faint radial furrows corresponding to the mesenteries. The conchula or the continuation of the upper end of the siphonoglyph is a prominent structure raised above the level of the oral disc and occurs between the mouth and the margin of the disc. There are five lobes on the conchula, of which one is terminal and situated to the outside, while among the others, a pair occurs on either side (Fig. 2). All the five lobes of the conchula of the adult anemone are almost of the same degree of development. The mouth occurs just beside the conchula; on one side, its wall is made up of the tubular siphonoglyph which is raised above the level of the disc. The throat is not open, and prominent throat ridges appear to be absent.

The Tentacles.—There are sixteen tentacles which are apparently disposed in two cycles, but are really formed of three cycles. Six of them are of a smaller size than the rest and they are the endocœlic tentacles, occurring innermost. The two directive tentacles also occur in the same whorl, but the tentacle corresponding to the directive chamber on the ventral side is distinctly smaller than the other directive, which is larger than all the endocœlic tentacles, but does not grow to the same size as the exocœlic ones. The innermost whorl thus consists of the first and second cycles of endocœlic tentacles. The third cycle of eight exocœlic tentacles occurs outermost; as in other species of *Peachia* they are the largest in the anemone. All the tentacles are blunt and have almost the same thickness throughout.

Anatomy of Peachia tropica.

The ectoderm and endoderm of the column are very thin layers, but the mesogleal layer is well developed and is many times thicker than the other layers. Mucus-cells appear to be absent from the ectoderm of the column. Nematocysts are scarce and are totally wanting in the lower end of the column.

The Actinopharynx.—The siphonoglyph and the actinopharynx are quite separate (Fig. 3), and the latter extends only for a short distance in the aboral direction. The stomodæum is without prominent ridges at its distal part, but lower down, a number of minute ridges occur. The distal part of the actinopharynx is not everted. The condition noticed here is in sharp contrast with another group of burrowing anemones, the Halcampactiidæ (*vide* Panikkar, 1936 and 1937). The siphonoglyph is a thick-walled tube extending for about half the length of the anemone, even after

the termination of the actinopharynx. This aboral extension is also a tube by itself (Fig. 3), without the opening on the side noticed for *Peachia hastata*

FIG. 3.

(Figs. 132 and 133, Carlgren, 1921). A strip of the actinopharynx is also associated with the siphonoglyph, and it is noticed even in sections taken lower down the column (Fig. 4).

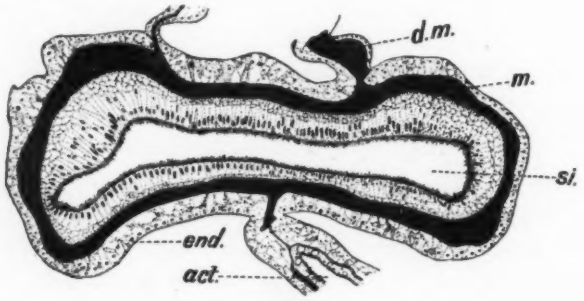


FIG. 4.

The Mesenteries.—There are on the whole sixteen mesenteries and among them there is no distinction into microcnemes and macrocnemes (Figs. 5 and 6). All of them are perfect and fertile and have well-developed retractors. They belong to two cycles, a primary set consisting of six pairs and a secondary set of two pairs. Each pair of the latter is found between the dorsolateral and ventrolateral *pairs* of primaries on either side. The four mesenteries belonging to the second cycle are uniformly developed; they do not reach as much lower down as the primaries. In the distal part

of the column the mesenteries belonging to the second cycle are almost of the same degree of development as the first. Mesenteries belonging to later cycles are not met with since there is no increase in the number of septa

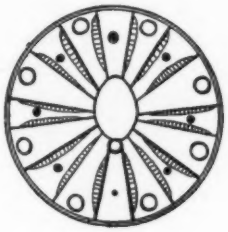


Fig. 5.

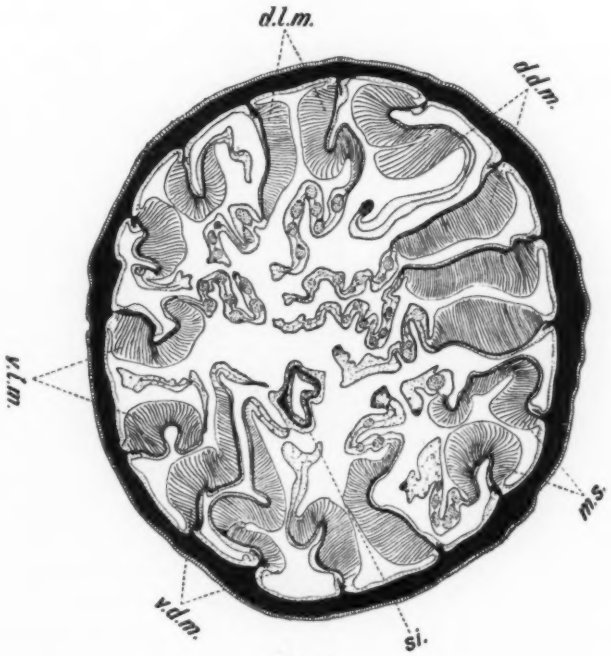


Fig. 6.

just below the oral disc. This has been ascertained only from living material as the oral disc region of the solitary specimen obtained has not been sectioned. The matter has, however, been settled beyond doubt by a careful study of the living specimen, and by the dissection of a part of the disc.

The mesenterial musculature is well developed. The retractors consist of long and numerous folds ; the individual folds are not notably branched (Fig. 7). The muscle folds do not have a reniform appearance in transverse sections because they are not sharply circumscribed. The muscle folds of the retractor are spread over the greater part of the mesentery and are similar to those of *Peachia hastata* in general appearance ; but as compared to the figure of a section of the species given by Stephenson (1928), the musculature of *P. tropica* appears to be much less diffuse. The retractors merge into the parietals without any distinct limit between the two. The parietals are well developed only on the side opposite the retractor muscle, since they are mainly concentrated on one side. The number of parietal folds generally varies from 5 to 8 ; and the folds are unbranched.

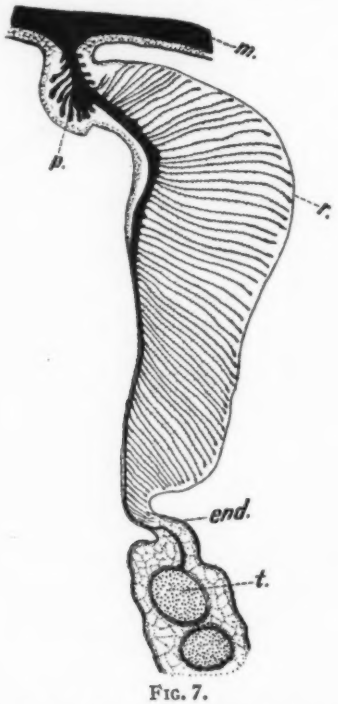


FIG. 7.

The retractor muscles of the second cycle of mesenteries are less diffuse than those of the first cycle. The parietal musculature of these mesenteries is notably weak. Of the mesenteries of the first cycle, the most diffuse ones are the dorsal and ventral directives, which are almost uniformly developed, thus differing from the condition noted for *Peachia hastata* (Carlgren, 1921).

The mesenterial filament is of the usual type and calls for no special remark. It is present on all the mesenteries ; but those found in the second cycle have much shorter filaments than in the first. The ciliated tract region of all mesenteries is considerably short and extends only for about a third of their lengths.

The gonads are borne by all the mesenteries, irrespective of the cycles to which they belong. The specimen studied in detail was a male, which had well-developed testes on all the mesenteries. The species is probably diœcious.

The Probable Order of Succession of Tentacles.

Since the mesenterial and tentacular arrangement of this anemone differs from other species of *Peachia*, it would be of interest to reconstruct the probable order of succession of mesenteries and tentacles from what could be studied from the relationships of the different cycles of mesenteries and tentacles. The morphological differences observed in this anemone are (1) the restriction of the mesenteries of the second cycle to two pairs of almost perfect mesenteries occurring only in one of the primary lateral exocœls lying on either side of the oral axis, while in all the other known species the secondary mesenteries occupy both the lateral and ventrolateral exocœls ; and (2) the increase in the number of tentacles from the usual number of twelve to sixteen. It is well known that owing to early parasitic life, the order of succession of the tentacles and the relation of the latter with the developing mesenteries in *Peachia*, are different from the typical condition observed for Actinians (Faurot, 1895 ; Carlgren, 1906 and 1921 ; and Stephenson, 1928). The ultimate result of this is that the endocœlic tentacles are shorter than the exocœlic ones. In *Peachia hastata* and other species with twelve tentacles, the development of the tentacles consists of two phases, *viz.*, (1) the development of the first eight tentacles arising from the inter-mesenterial spaces of the first eight Edwardsia mesenteries ; and (2) the almost simultaneous origin of the next four tentacles that ultimately become endocœlic. The disposition of the mesenteries and tentacles of this species and the presence of the additional four tentacles involve necessarily a third phase of development.

The relationship of the mesenteries and the tentacles of the adult *Peachia tropica* is represented in Fig. 5. Judged from the sizes of the tentacles of the anemone while alive, the degree of development of the mesenteries as judged from sections, and what we know of their development in other species of *Peachia* from the work of Carlgren (1906) and Faurot (1895), the following order may be regarded as probable. The first-

formed eight tentacles as seen in the adult are the two directives, the exocœlic tentacles lying on either side of the directives, four in all, and another lateral pair of tentacles which are exocœlic. As mentioned before, the directive tentacle lying opposite the conchula on the ventral side is smaller than the others belonging to the same cycle. This is due to the fact that its growth is to a certain extent retarded by the formation of the conchula and the incidental disturbances on the sulcar side of the oral disc during the post-larval phase. The next four tentacles to make their appearance are the endocœlic ones disposed in relation with the lateral pairs of *primary mesenteries*. It is the growth of these four tentacles that has deflected the lateral primary tentacles belonging to the first set, to their present positions, *i.e.*, on the exocœls adjoining the directives. As in other species of *Peachia*, these four are of a smaller size when compared with the rest. The tentacles that appear to develop last are the two endocœlic ones in relation with the two pairs of mesenteries of the second cycle, and the two exocœlic ones adjoining them. It has been demonstrated by Faurot (1895) that the second set of four tentacles in *Peachia hastata* arises almost simultaneously. It is probable that this is true for other species also. In most Actinians, the development of the tentacles after the first twelve have formed, is somewhat irregular as the corresponding tentacles on either side of the directive axis do not often originate simultaneously. It is not possible to ascertain definitely whether the development of the third set of tentacles and mesenteries in *Peachia tropica* is irregular or simultaneous as in the case of the second set. If the size of the tentacles on the two sides is a proper index on this matter, they appear to develop more or less at the same time.

The mesenteries of the second order seem to develop very late in most species of the genus *Peachia* (Carlgren, 1921). Hence they do not attain the same degree of development as the primaries, though they may have retractors and gonads like the latter. In *Peachia tropica*, however, the distinction between the primary and secondary cycles of mesenteries is to a great extent obliterated as the latter develop almost to the same extent of development as the primaries.

Systematic Relationships.

The species of *Peachia* already described are :—

1. *Peachia hastata* Gosse, 1855. (For synonymy, *vide* Haddon and Dixon, 1885.) The species *P. undata* Gosse, 1858, and *P. triphylla* Gosse, 1860, are only varieties of *P. hastata*. For literature, *vide* Stephenson, 1935.
2. *Peachia parasitica* (L. Agass). Verrill, 1866. (*Vide* Carlgren, 1921.)

3. *Peachia carnea* Hutton, 1879.
4. *Peachia koreni* McMurrich, 1893.
5. *Peachia hilli* Wilsmore, 1911.
6. *Peachia quinquecapitata* McMurrich, 1913.
7. *Peachia bœcki* Carlgren, 1921.
8. *Peachia neo-zealanica* Carlgren, 1924.
9. *Peachia chiliensis* Carlgren, 1931.

All the known species have only up to twelve tentacles; *P. koreni* and *P. neo-zealanica* have a smaller number of eight and ten respectively. The usual number of mesenteries is ten pairs, six perfect and four imperfect. In *P. neo-zealanica*, there is a great reduction of the later mesenteries of the primary cycle since the fifth and sixth couples are weakly developed, while the second cycle of mesenteries is represented by a weak unpaired septum arising from each lateral endocœl. The later mesenteries do not develop at all in *Peachia chiliensis*, where there are only eight perfect mesenteries, the last two couples of mesenteries completing the first cycle of twelve remaining in an imperfect condition. A certain amount of imperfection of the mesenteries of the primary cycle also exists in *Pachia hilli*, though four pairs of imperfect mesenteries are observed in this species. The affinities of *Peachia tropica* with the above species are much less pronounced than with the remaining species where the mesenteries have undergone greater organization. Thus in all the other species, *P. hastata*, *P. parasitica*, *P. carnea*, *P. quinquecapitata* and *P. bœcki*, the first cycle of mesenteries is completely developed in the column, and they have, in addition, the full quota of imperfect septa, *i.e.*, four pairs. Among these, *Peachia hastata* appears to be the species that is related more closely to *P. tropica*, judged from the great development of the conchula, and the robust nature of the mesenteries of both the species. However, the development of the gonads and filaments in the mesenteries belonging to the second cycle has not been observed in any other species than *P. tropica*, which is also unique in the development of an additional set of four tentacles. Side by side with the increase in the prominence of the second cycle of mesenteries, a reduction has also taken place in their number from the usual condition of four pairs to two pairs. Since these facts are against the usual condition in the known members of the genus, on which the present definition of the genus is based, a redefinition of *Peachia* is necessary to accommodate this new species.

PART II.

Observations on the Development of *Peachia* Larvæ.

Historical Introduction.

The larvæ of *Peachia* have formed the subject of many contributions, both scientific and semi-scientific, by several naturalists in different parts of the world. The observations of Andres (1881), Dixon (1891), McIntosh (1887), Muller (1860) and Verrill (1873) are specially noteworthy. The larvæ were considered by many as a distinct parasitic Actinian genus, for which the names *Bicidium*, *Bicidiopsis* and *Philomedusa* have variously been given (McMurrich, 1913). Haddon (1887) in his earlier contributions, thought it to be the larva of *Halcampa chrysanthellum*, but the fact that they are larval stages of the genus *Peachia*, was clearly demonstrated by Carlgren (1906 and 1921). The parasitic larvæ are at present known from different parts of the world, as for example N.W. Europe (Carlgren, 1921 ; Stephenson, 1935), Mediterranean (Faurot, 1890), North Atlantic and North Pacific (McMurrich, 1913), Australia (Badham, 1917 ; Wilsmore, 1911) and Japan (Uchida, 1928 and 1933). As noted in the previous section for the adult of *Peachia*, there is no previous record of the larvæ from the tropics so far as the author is aware. They occur on various Hydromedusæ and Scyphomedusæ during their early larval stages. Certain aspects of development have been dealt with both by Carlgren (1906) and Faurot (1890) in their account of the larvæ of *Peachia hastata* ; and Badham (1·17) has made some observations on the later larval stages of *Peachia hilli*, originally described by Wilsmore (1911). There are many gaps in our knowledge of the development of even these species, while practically nothing is known of others. The following account, though by no means exhaustive, deals with certain aspects of development which have not received proper attention in previous contributions.

Actinian larvæ parasitic on jelly fishes and Ctenophores have been observed for the genera *Peachia*, *Milne-Edwardsia* and *Edwardsia* ; and Stephenson (1935) suggests that they may possibly occur also in *Eloactis*, *Haloclava*, *Ilyanthus* and *Halcampella*. Most of these genera are exceptional in having the outermost tentacles longer than the innermost, a condition quite contrary to what occurs in typical Actiniaria. The presence of œsophageal lobes, the disc-shaped body and the development of the conchula, prove definitely that the larvæ described here belong to *Peachia* and to no other genus. At present, I am not in a position to say definitely whether or not they are young stages of *Peachia tropica* itself, though on circumstantial evidence, this may be considered most probable as the locality from

which the larvæ and adults have been collected is the same. Further, the fact that the directive tentacle is slow to develop in these larvæ, and that in the adult *Peachia tropica* the directive tentacle is distinctly smaller than others of the same cycle, renders this probability almost certain. Another convincing evidence is afforded by the fact that the complete separation of the siphonoglyph from the rest of the actinopharynx which was described for *P. tropica*, is observed to take place in the later stages of the larvæ.

Notes on Larvæ.

Occurrence.—The larvæ of *Peachia* found at Madras are parasitic on *Aequorea pensile* Modeer, a common Hydromedusa of the Madras plankton. They are attached to the sub-umbrellar surface of the jelly-fish, especially between the margin and the mouth. Specimens with 4 to 12 mesenteries have been found on the jelly-fish, and the following observations are from a number of larvæ collected during 1935-36. Their period of occurrence in the plankton is from November to March, the majority of the early stages having been obtained during November and December. The largest larvæ were caught during March. The larvæ are not at all common in the plankton, and are encountered only now and then; this probably accounts for their having not been recorded previously.

General.—The larvæ are beautifully transparent and reveal the interior structures clearly from the outside. The smaller individuals are disc-shaped; but, with growth, they assume gradually a conical column, and are fairly elongated by the time they are about to fall down from the jelly-fish. The specimens are attached by their oral faces. The disc-shaped appearance of the youngest individuals is retained till the end of the eight-mesentery stages, when the elongation of the aboral region commences. The column is distinct and separate from the oral disc at the end of the 12-mesentery stages, when the tentacles also begin to appear. The whole body of the larva is ciliated during the early stages, but the cilia of the column are not apparent in older larvæ, though they are distinct in the oral disc region.

4-6-Mesentery Stages.—The stages prior to the *Edwardsia* or eight-rayed stage are minute and have a diameter of less than a millimetre. In the four-mesentery stage, the dorso-lateral as well as the ventrolateral couples have made their appearance and soon they extend to the centre of the disc. As yet there is no trace of the directives. The mesenteries already formed are very thin lamellæ and do not present thickenings along their free borders. The mouth is small and insignificant during this stage and there is no aboral pore. In the six-mesentery stage, the ventral directives have also appeared in addition to the dorso-lateral and ventrolateral couples. As yet there is

no difference between the aboral and oral faces of the larva except for the central perforation of the mouth in the latter.

Eight-Mesentery Stages.—With the development of the dorsal couples or the dorsal directive mesenteries which now takes place, the larva attains the *Edwardsia*-stage of development. During the early *Edwardsia*-stages, only the first two couples of mesenteries extend to the actinopharynx while the two pairs of directives are not completed. The first set of directives to complete the connexion with the actinopharynx is the ventral one. At this stage, the aboral pore is seen in some of the specimens collected, while it is absent in others ; nor are any minute openings of the nature of cinclides observed.

The histological elements of the column are not well differentiated during this stage. The ectoderm is crowded with interstitial elements that stain darkly in hæmatoxylin. Gland cells, mucus-cells and nematocysts are totally absent from the anemone. The first type of capsule to develop is the spirocyst which begins to appear at the end of the *Edwardsia*-stage. Distinct cell boundaries are not apparent in the ectoderm and endoderm in preparations from material fixed in Bouin Duboscq as well as corrosive sublimate. The mesogleal layer contains a number of scattered nuclei.

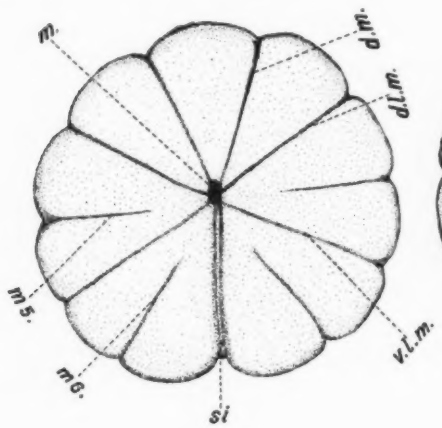


Fig. 8.

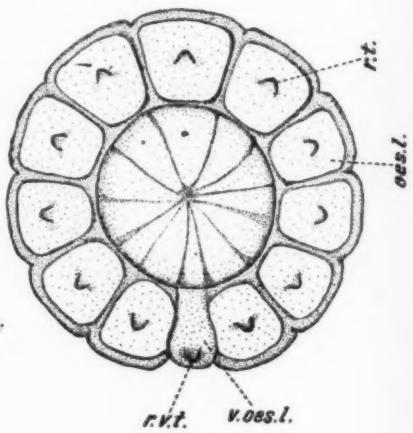


Fig. 9.

Twelve-Mesentery Stages.—The fifth and sixth couples of mesenteries appear almost simultaneously and their disposition with those already formed is the same as that noted by Faurot (1895) for *Peachia hastata.* The differentiation of the column from the oral disc region takes place now, and important changes in the region of the oral disc of the larva occur

during this stage as will be described below. The ventro-lateral and dorso-lateral couples of mesenteries show club-shaped thickenings on their free borders. This represents the developing filament which at first consists only of the cnidoglandular tract. The actinopharynx begins to extend in the region of the column and appears in sections, for a very short distance. Siphonoglyphs are not present up to this stage. At the end of the twelve-mesentery stage, the larva is provided with a conical column, an oral disc that has considerably expanded by its inter-mesenterial spaces being prolonged as œsophageal lobes in continuation with the throat. The tentacles are not distinct up to this stage, but they begin to differentiate immediately after the formation of the tubular siphonoglyph is completed.

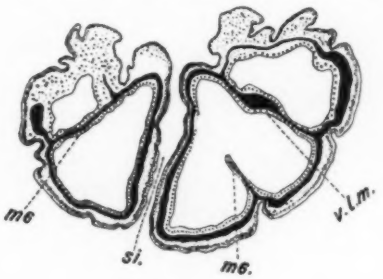


FIG. 10.

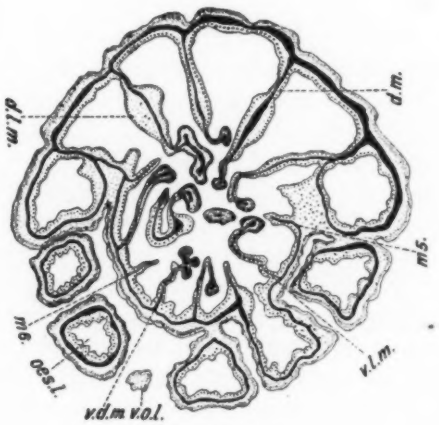


FIG. 11.

Spirocysts are present in the column during the 12-mesentery stages, and a faint trace of ectodermal longitudinal musculature is also noticed in sections (Fig. 13). In other respects the histology is similar to that of the eight-mesentery stages described above.

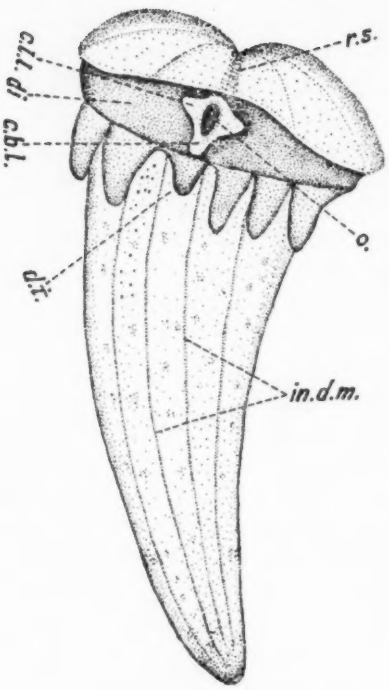


Fig. 12.

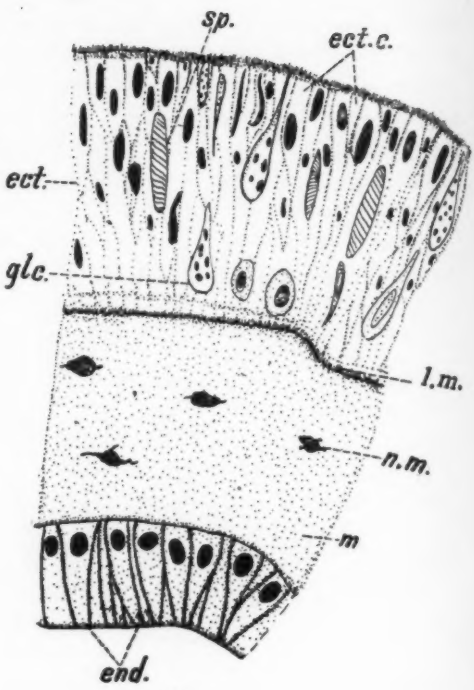


Fig. 13.

Oesophageal Lobes.—It was mentioned that the attachment of the larva on the jelly-fish is by its oral surface which is closely applied to the host and acts something like a sucker. This part consists of the central mouth, the throat and the oral disc of the larva. The space between the margin and the central orifice of the mouth (which is really the enterostome of the adult) is mainly composed of the actinopharynx, which in virtue of the flattened condition of the larva brought about by parasitic existence, has become confluent with the oral disc, instead of growing as a tube leading into the cœlenteron. If we examine a larva that has attained the twelve-mesentery stage, the central mouth and the six pairs of mesenteries radiating from it could be easily distinguished, with the inter-mesenterial spaces more or less equal, though the ventral directive mesenteries are even now closely situated. At the periphery of the oral face of the larva these inter-mesenterial spaces are slightly prolonged in the radial direction so as to ensure the proper attachment of the larva to the host. These prolongations are the œsophageal lobes, because they are mainly composed of the actino-pharynx that has undergone partial eversion.

Development of the Siphonoglyph and Conchula.—In larvæ slightly older than the previous ones, the œsophageal lobe between the two ventral directive mesenteries is seen to gradually shift its position from the rest. Viewed from the oral side, it is seen to gradually sink down, in between the two adjoining œsophageal lobes, so that a distinct groove is noticeable, leading from the mouth to the periphery of the larva. The groove is situated between the two ventral directive mesenteries and is closely adpressed by the œsophageal lobe on either side, and the œsophageal lobe between the ventral directives constitutes its floor. This channel is the developing siphonoglyph. With the growth of the larva it deepens down and the adjoining œsophageal lobes approach closer and closer. These changes are over before the 5th and 6th couples of mesenteries have completed their full development.

Examination of living larvæ as well as of sections shows that this channel is powerfully ciliated. A regular current of water may be seen passing into the larva. When the larva is closely applied to the jelly-fish, it is clear that the mouth is completely shut off from the exterior and that this channel is the only possible communication. There is not the least doubt that the purpose of the ciliary current is for feeding. It may also be mentioned here that the larvæ were without any food in the cœlenteron up to this stage, but diatoms and copepods were noticed from this stage onwards. The aboral region did not have minute pores during this stage.

With the development of the siphonoglyph, the other œsophageal lobes also increase in size. On their edges away from the mouth, and facing the aboral side, a minute papilla appears on each œsophageal lobe. These are the rudiments of the tentacles whose development remains arrested for some time. The ventral œsophageal lobe has by this time got completely isolated from the rest; and in an oral view of the larva, only eleven lobes could be made out, the ventral one being completely sunk beneath and the adjoining lobes having come close together (Fig. 8). In course of time, they unite and roof over the channel or the siphonoglyph and thus completes its tubular structure. This tube extends from the mouth to the external opening of the former, which is situated between the ventral œsophageal lobe which may be seen in an aboral view of the larva (Fig. 9), and its two adjoining lobes. This opening is not visible from the oral side of the larva. The base of the ventral œsophageal lobe extends round the latter opening in the course of later development, and contributes to the formation of the conchula. The tip of the lobe is taken up by the rudiment of the ventral directive tentacle, which is slow to develop as compared with the others.

The delay in its development is due to the change in position of its corresponding œsophageal lobe and the development of the conchula from its basal part. The conchula consists only of three lobes during the early stages, but an additional pair is developed between the first three as the animal grows.

Pores on the Physa and the Aboral Pore.—The pores on the physa described by Badham (1917), Wilsmore (1911) and Haddon (1897) are not present in the larvæ until a comparatively late stage of development. They make their appearance by the time the larvæ are about to be liberated from the host. The pores are extremely small and could be distinguished only under the microscope. A single row of them occurs on each inter-mesenterial space, irrespective of its being an exocœl or an endocœl. The pores are without cinclis lips; and I have not been able to detect them in longitudinal sections of the larvæ.

Badham (1917) correlates the development of the pores of the physa with the occurrence of the conchula, as it would enable a constant stream of water to pass through the body of the larval anemone, entering by the conchular opening and escaping through the pores of the physa. In the species that he studied, these pores are especially well developed. In the Madras species, the pores do not appear to be of the same importance as in *P. hilli* studied by Badham, where the parasitic life is considerably prolonged as the larvæ are lodged inside the canals of the jelly-fish *Crambessa mosaica.*

There is considerable discrepancy in the previous accounts of the *Peachia* larvæ in regard to the occurrence or otherwise of an aboral pore. My observations on living larvæ show that at least in the Madras species, there is no aboral pore to begin with. This is so with many of the specimens belonging to different stages examined by me. Openings found in a few instances appear to have been the result of some kind of injury to the larvæ in question.

End of Larval Phase.—The differentiation of the tentacles takes place immediately after the completion of the conchula, but they do not lengthen out so long as the larvæ remain attached. It may be emphasized here that during the attached condition there is no strict demarcation between the œsophageal lobes and the tentacles.

The largest specimen obtained from the jelly-fish had a length of 13 mm. and a maximum width of 7 mm. On one occasion, an almost young anemone 16 mm. long was obtained from the plankton in a free state. In the latter, the tentacles had developed to a slightly larger size and the oral disc was not expanded as in the larva since the bases of the tentacles had come much

closer. This suggests that after liberation, the everted actinopharynx is tucked in. When the specimen was narcotized in menthol for fixation, the throat was again everted and the individual assumed almost the same appearance of an attached larva ; but it did not show any tendency to cling to the jelly-fish, though it was removed to fresh sea-water, revived, and placed on a living specimen of *Aequorea*. The same anemone in the preserved state is illustrated in Fig. 12. These facts suggest that the larvæ drop down during this stage

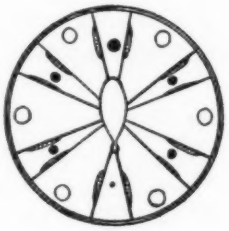


Fig. 14.

The young individuals hitherto obtained have only twelve tentacles, and if the assumption made here that the larvæ belong to *Peachia tropica* is correct, the development of the additional four tentacles takes place only after the larvæ have settled on the bottom. This must also be true of the second cycle of mesenteries.

Discussion.

The occurrence of the adults and medusophilous larvæ of the genus *Peachia* on the Madras coast brings additional evidence in support of the view first advanced by Badham (1917) that the genus is widely distributed and that the larval stages of all the members of the genus are parasitic. The greater prominence of the exocœlic tentacles over the endocœlic ones, and the development of the highly specialised siphonoglyph and the conchula are observed in all the known species ; these are obviously features brought about by the parasitic existence of the larva. The effect of parasitism upon the development of tentacles has been particularly manifest since the very peculiar disposition and formation of the last four tentacles have, to a certain extent, acted as a definite check on the further growth of the tentacles. Thus, in many species, we find later sets of mesenteries arising from the lateral and ventrolateral exocœls, but the corresponding tentacles are not developed. Though a total number of twenty mesenteries often exists, not more than twelve tentacles are observed ; and the original tentacular arrangement is kept up in spite of the formation of additional septa. In this respect,

the genus *Peachia* is in sharp contrast with the nearest related genera, especially genus *Ilyanthus*. In *Peachia tropica*, however, we have a species in which, unlike the other forms, the original arrangement is interfered with by the development of a new cycle of tentacles, so that the final arrangement is in exact agreement with the number of mesenteries. In the increase of tentacles and in the greater prominence and fertility of the second cycle of septa that grow in the lateral exocœls, the condition in *Peachia tropica* is suggestive of the tendencies operative in the evolution of the genus *Ilyanthus*, in which the disposition of the mesenteries and tentacles is definitely bilateral; the mesenteries are equal in number to the tentacles; all the mesenteries are macrocnemes; and the largest, or all of them are fertile (Stephenson, 1935).

The suggestion that the conchula has been developed as a larval organ correlated with the parasitic existence of the larval forms of *Peachia* has been put forth by Badham (1917) from his observations on the development of *Peachia hilli*. It is probably more precise to say that the independent opening of the siphonoglyph can be correlated with the fact that the larvæ are attached by their throats, since the actual formation of the conchula takes place only at the end of the larval phase. In the development of the Madras larvæ, the formation of the deep siphonoglyph and its gradual shifting of position until its opening occurs on one side independent of the actinopharynx are some of the most important changes taking place in the larva after the completion of the twelve mesenteries. It was emphasized in the account of development that the conchula originates from the ventral œsophageal lobe of the larva, which in turn is really a part of the actinopharynx that has undergone eversion for the sake of attachment to the host. It becomes thus evident that irrespective of its structure and position, the conchula of the adult *Peachia* is homologous with a part of the larval actinopharynx.

Summary.

1. Both the larval stages and the adults of the genus *Peachia* are recorded from Madras. The adult anemone is described as a new species *Peachia tropica*.

2. The morphology of *Peachia tropica* is described. The anemone has a vermiform column, a five-lobed conchula and sixteen tentacles. The mesenteries consist of a primary cycle of six pairs and a secondary set of two pairs; they are arranged without distinction into macrocnemes and microcnemes. All mesenteries are fertile and have filaments. The siphonoglyph is completely separate from the actinopharynx.

3. The number of tentacles and disposition of mesenteries are unique features of *P. tropica* as compared to other species of the genus ; the probable order of succession of mesenteries and tentacles in the light of this new arrangement is discussed.

4. The systematic relationships of the anemone are discussed.

5. Parasitic larvæ from *Aequorea pensile* are described and the development of the larva from the 4 to 12 mesentery stage is followed.

6. The development of the œsophageal lobes, siphonoglyph and the conchula is described in detail.

7. The conchula is developed from the base of the ventral œsophageal lobe.

8. The larvæ drop down after the twelve-mesentery stage, when they are from 13 to 16 mm. long.

9. The development of the second cycle of mesenteries and the related tentacles appear to take place only after the larvæ have left the host.

10. The influence of the parasitic life of the larvæ on the adult structure of *Peachia* is discussed.

Acknowledgment.

In conclusion, I wish to thank Professor R. Gopala Aiyar, Director, University Zoological Laboratory, Madras, for numerous suggestions and very valuable criticism.

BIBLIOGRAPHY.

Andres, A. .. .. "Prodromus Neapolitanæ Actiniarum Faunæ," *Mitt. Zool. Stat. Neapel*, 1881, Bd. 2.

———— .. .. "Le Attinie," *Fauna u. Flora des Golfe von Neapel*, Monogr. 9, 1883.

Appellof, A. .. .. "Die Aktiniengattungen *Fenja*, *Aegir*, and *Halcampoides* Dan.," *Bergens Mus. Aarbok*, 1881, 11.

Badham, C. .. .. "On a larval Actinian parasitic on a Rhizostome," *Quart. Journ. Micr. Sci.*, 1917, 62.

Carlgren, O. .. .. "Uber *Pentactinia californica* n.g., n.sp.," *Ofvers K. Vetensk. Akad. Forh. Stockholm*, 1900, Bd. 57.

———— .. .. "Kurze Mitteilimgen uber Anthozoen, Pts. 1–4," *Zool. Anz. Leipzig*, 1904–1905, Bd. 27 & 28.

———— .. .. *Die Aktinien Larven. Nordisches Plankton*, 1906, Bd. 11, No. 5, Keil and Leipzig.

———— .. .. *Actiniaria: The Danish Ingolf Expedition*, 1921, 5, Pt. 9, Copenhagen.

———— .. .. "Actiniaria from New Zealand and its Sub-Antarctic Islands": Papers from Dr. Th. Mortensen's Pacific Expedition, *Vid. Med. Dansk. Naturhist. Foren*, 1924, Bd. 77.

Carlgren, O. .. .. "Zur Kentniss der Actiniaria Abasilaria," *Ark. Zool. Stockholm*, 1931, Bd. **24**.

Danielssen, D. C. .. .. "Actinida": *Norske Nordhavs Expedition*, 1890, **19**, Christiania.

Dendy, A. F. .. .. "Notes on some Actinian larvæ parasitic upon a medusa from Port Philip," *Proc. Roy. Soc., Victoria*, 1889, **1**.

Dixon, G. Y. & A. F. .. "Report on the marine invertebrate fauna near Dublin," *Proc. Roy. Irish Acad.*, Ser. 3, 1891, **2**.

Faurot, L. .. .. "Sur la disposition des cloisons mesenteroides chez la *Peachia hastata*," *C. R. Acad. Sci., Paris*, 1890, T. 110.

———— .. .. "Etudes sur l'anatomie, l'histologie et la developpement des Actinies," *Arch. Zool. Exper. Gen.*, Ser. 3, 1895, **3**.

Gosse, P. H. "Description of *Peachia hastata*, a new genus and species of the Class Zoophyta, with observations on the family Actiniadæ," *Trans. Linn. Soc. Zool., London*, 1885, **21**.

———— .. .. *Actinologia Britannica: A history of British Sea Anemones and Corals, London*, 1860.

Haddon, A. C. .. .. "On the arrangement of the mesenteries in the parasitic larva of *Halcampa chrysanthellum* (Peach)," *Sci. Proc. Roy. Dublin Soc.*, 1887, **4**.

———— .. .. "On larval Actiniæ parasitic on Hydromedusæ at St. Andrews," *Ann. Mag. Nat. Hist.*, Ser. 6, 1888, **2**.

———— .. .. "A revision of the British Actiniæ, Pt. I," *Sci. Trans. Roy. Dublin Soc.*, Ser. 2, 1889, **4**.

Haddon, A. C., and Dixon, G. Y. "The structure and habits of *Peachia hastata* (Gosse)," *Sci. Proc. Roy. Dublin Soc., N.S.*, 1885, **4**.

Hutton, H. W. .. .. "Contribution to the Cœlenterate fauna of New Zeland," *Trans. New Zealand Inst.*, 1879, **12**.

Lebour, M. V. .. .. "The microplankton of Plymouth Sound, from the region beyond the breakewater," *Journ. Mar. Biol. Assoc.*, 1917, **11**.

Mark, E. L. .. .. "Drawings from an unpublished paper by E. L. Mark," *Mem. Harv. Mus. Comp. Zool., Cambridge, Mass.*, 1884, **9**.

McIntosh, W. C. .. .. "On the commensalistic habits of the larval forms of *Peachia*," *Ann. Mag. Nat. Hist.*, Ser. 5, 1887, **20**.

McMurrich, J. P. .. .. "Report on the Actiniæ collected by the U.S. Fish. Comm. *Proc. U.S., Nat. Mus.*, 1893, **16**.

———— .. .. "On two new Actinians from British Columbia," *Proc. Zool. Soc., London*, 1913.

Menon, K. R. .. .. "Zoantharia: Littoral Fauna of Krusadi Islands and the Gulf of Mannar," *Bull. Madras Govt. Mus. N.H., N.S.*, 1927, **1**.

Monticelli, F. S. .. .. "Sulla larva di *Edwardsia claparedi* Panceri," *Mitt. Zool. Stat. Neapel*, 1927, **13**.

Muller, F. .. .. "Ueber *Philomedusa vogtii*," *Arch. Naturg*, 1860, **26**.

Panikkar, N. Kesava .. "The Structure, Bionomics and Systematic position of two new Brackish-water Actiniaria from Madras," *Proc. Zool. Soc., London*, Pt. 1, 1936.

———— .. .. "A Study of the Actinian *Phytocætes gangeticus* Annandale, with an account of the post-larval development and the occurrence of Neoteny in the Anemone," *Zool. Jahrb. Abt. Anat. u. Ont. Jena*, 1937, Bd. **62**.

Pax, F. .. .. "Cœlenterata: Unterklasse Hexacorallia," Kukenthal and Krumbach's *Handbuch der Zoologie*, 1925, Bd. **1**, Lg. 2.

Sedgwick, A. .. .. "On the origin of metameric segmentation and some other morphological questions," *Quart. Journ. Micr. Sci.*, 1884, **24**.

Stephenson, T. A. .. .. "On the classification of the Actiniaria, Pts. I–III," *ibid.*, 1920–22, **64–66**.

———— .. .. "The Genus *Ilyanthus* Forbes," *Journ. Mar. Biol. Assoc.*, 1922, **12**.

———— .. .. *The British Sea Anemones*, 1928, **1**, *Ray Soc. Monograph.*

———— .. .. "On the nematocysts of Sea anemones," *Journ. Mar. Biol. Assoc.*, 1929, **16**.

———— .. .. *The British Sea Anemones*, 1935, **2**, *Ray Soc. Monograph.*

Uchida, T. .. .. "Notes on the Actinian larva parasitic on a Leptomedusa,' *Proc. Imp. Acd., Tokyo*, 1928, **4**.

———— .. .. "On a medusophilous Actinian from Mutsu Bay," *ibid.*, 1932, **8**.

Verrill, A. E. .. .. "Exploration of Casco Bay by the U.S. Fish Commission in 1873," *Proc. Amer. Assos. Adv. Sci.*, 1873, **22**.

Wilsmore, L. J. .. .. "On some Hexactiniæ from New South Wales," *Journ. Linn. Soc. Zool., London*, 1911, **32**.

EXPLANATION OF TEXT-FIGURES.

FIGURE 1. *Peachia tropica* n.sp.—External view. Drawn from a living specimen. *ph.*—aboral region corresponding to the physa; *Sc.*—region of the column corresponding to the scapus; *t.*—tentacle.

FIGURE 2. *P. tropica.*—Oral view of the conchula, showing one median and four lateral lobes. *l.l.*—lateral lobes; *m.l.*—median lobe; *o.*—opening of the siphonoglyph.

FIGURE 3. *P. tropica.* Section passing through the upper region of the actinopharynx, showing the separate siphonoglyph and the sixteen mesenteries. Drawn from a hand section. Magnified about thirty times. *act.*—actinopharynx; *d.m.*—ventral directive mesenteries; *si.*—tubular siphonoglyph; *s.m.*—a pair of mesenteries belonging to the second cycle.

FIGURE 4. Transverse section through the aboral extension of the siphonoglyph, along with the minute strip of the actinopharynx. × 250. *act.*—strip of the actinopharynx; *d.m.*—ventral directive mesentery; *end.*—endoderm; *m.*—mesoglea; *si.*—lumen of the tubular siphonoglyph.

FIGURE 5. The scheme of arrangement of mesenteries and tentacles of *Peachia tropica*. In the representation of the tentacles distinction is not made between the two sets of endocœlic tentacles. The ventral directive is distinctly smaller than the other tentacles, and the largest tentacles are the outer eight exocœlic ones which are unshaded in the figure.

FIGURE 6. *P. tropica*.—Transverse section through the middle portion of the anemone, below the region of the actinopharynx, showing the eight pairs of mesenteries, gonads and the tubular siphonoglyph. × 30. *d.d.m.*—dorsal directive mesenteries; *d.l.m.*—mesenteries of the dorso-lateral pair; *m.s.*—a pair of mesenteries belonging to the second cycle, situated in the lateral exocœls of the primary pairs; *si.*—aboral extension of the siphonoglyph; *v.d.m.*—ventral directive mesenteries; *v.l.m.*—mesenteries of the ventro-lateral pair.

FIGURE 7. Transverse section through the mesenterial muscles of *P. tropica*, also showing part of the gonads. The mesentery illustrated is one belonging to the dorso-lateral couple. × 250. *end.*—endoderm of the mesentery; *m.*—mesoglea; *p.*—parietal muscles; *r.*—retractor muscles; *t.*—testis.

FIGURE 8. Oral view of a larva of *Peachia* belonging to the twelve-mesentery stage. Magnified about twenty times. Only eleven of the œsophageal lobes are seen in this view as the ventral œsophageal lobe has sunk below the oral surface. *d.m.*—dorsal directive mesentery; *d.l.m.*—mesentery belonging to the dorso-lateral couple; *m.*—mouth; *m*5 and *m*6—mesenteries belonging to the fifth and sixth couples. *si.*—the developing syphonoglyph which at this stage is in the form of an open channel; *v.l.m.*—mesentery belonging to the ventro-lateral couple.

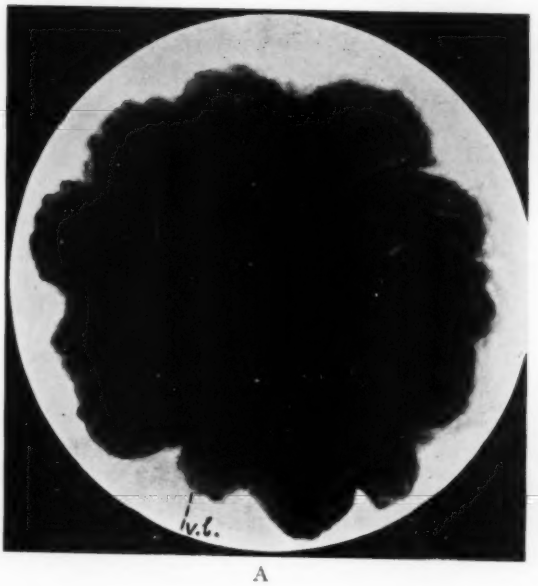
FIGURE 9. Aboral view of the same larva as illustrated in Fig. 8. Magnified about twenty times. *oes.l.*—one of the œsophageal lobes; *r.t.*—rudiment of a tentacle; *r.v.t.*—rudiment of the ventral directive tentacle; *v.oes.l.*—ventral œsophageal lobe which is seen in this view of the larva.

FIGURE 10. Horizontal section through a larva with twelve mesenteries, passing through the siphonoglyph which is an almost closed channel disposed radially. The section is slightly oblique so that the entire larva has not come in the field. × 40. *m*6.—the last couple of mesenteries belonging to the primary cycle; *si.*—siphonoglyph; *v.l.m.*—a mesentery belonging to the ventrolateral couple.

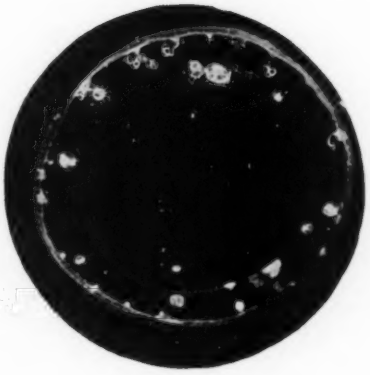
FIGURE 11. Transverse section through a larva in the twelve-mesentery stage showing part of the column and the oesophageal lobes. × 50. *d.m.*—dorsal directive mesentery; *d.l.m.*—dorso-lateral mesentery; *m*5 and *m*6.—mesenteries of the fifth and sixth couples; *oes.l.*—oesophageal lobe; *v.d.m.*—ventral directive mesentery; *v.l.m.*—mesentery belonging to the ventro-lateral couple; *v.o.l.*—part of the ventral œsophageal lobe which is not in the same plane as the other lobes.

FIGURE 12. Side view of the oldest larva obtained, drawn from a preserved specimen. Magnified about five times. *c.b.l.*—basal (median) lobe of the conchula; *c.l.l.*—lateral lobes of the conchula; *d.t.*—directive tentacle (ventral) which is distinctly smaller than others. *di.*—the space that corresponds to the oral disc of the adult; *in.d.m.*—insertions of the ventral directive mesenteries; *o.*—external opening of the siphonoglyph; *r.s.*—roof of the siphonoglyph seen in the everted throat.

FIGURE 13. Transverse section of the column near the œsophageal lobe of a larva in the late twelve-mesentery stage. × 750. *ect.*—ectoderm; *ect.c.*—the ground



A



B

ectodermal cells; *end.*—endodermal cells; *gl.c.*—gland cells; *l.m.*—feeble longitudiinal musculature that disappears in the adult; *m.*—mesoglea; *n.m.*—scattered nuclei of the mesoglea; *sp.*—spirocyst.

FIGURE 14. Scheme of arrangement of mesenteries and tentacles of the late larval stages of *Peachia*. The six exocœlic tentacles unshaded, the six endocœlic ones shaded. The ventral directive tentacle is shown as being smaller than the other tentacles (Compare Figure 12).

EXPLANATION OF PLATE XXIV.

A. Photomicrograph of a larva of *Peachia* belonging to the twelve mesentery stage of development. The view is aboral and only the œsophageal lobes are in focus. The ventral œsophageal lobe (*v.l.*) is seen distinctly smaller than those on the two sides. 4 × 8, bellows extension 10 inches.

B. Photograph of a specimen of *Aequorea pensile*, with a number of parasitic *Peachia* larvæ. From living material. About the natural size.

A STUDY OF *AITCHISONIELLA HIMALAYENSIS* KASH.

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Received March 19, 1938.

[Communicated by Dr. H. Chaudhuri, M.A., Ph.D., D.Sc. (Lond.), D.I.C.]

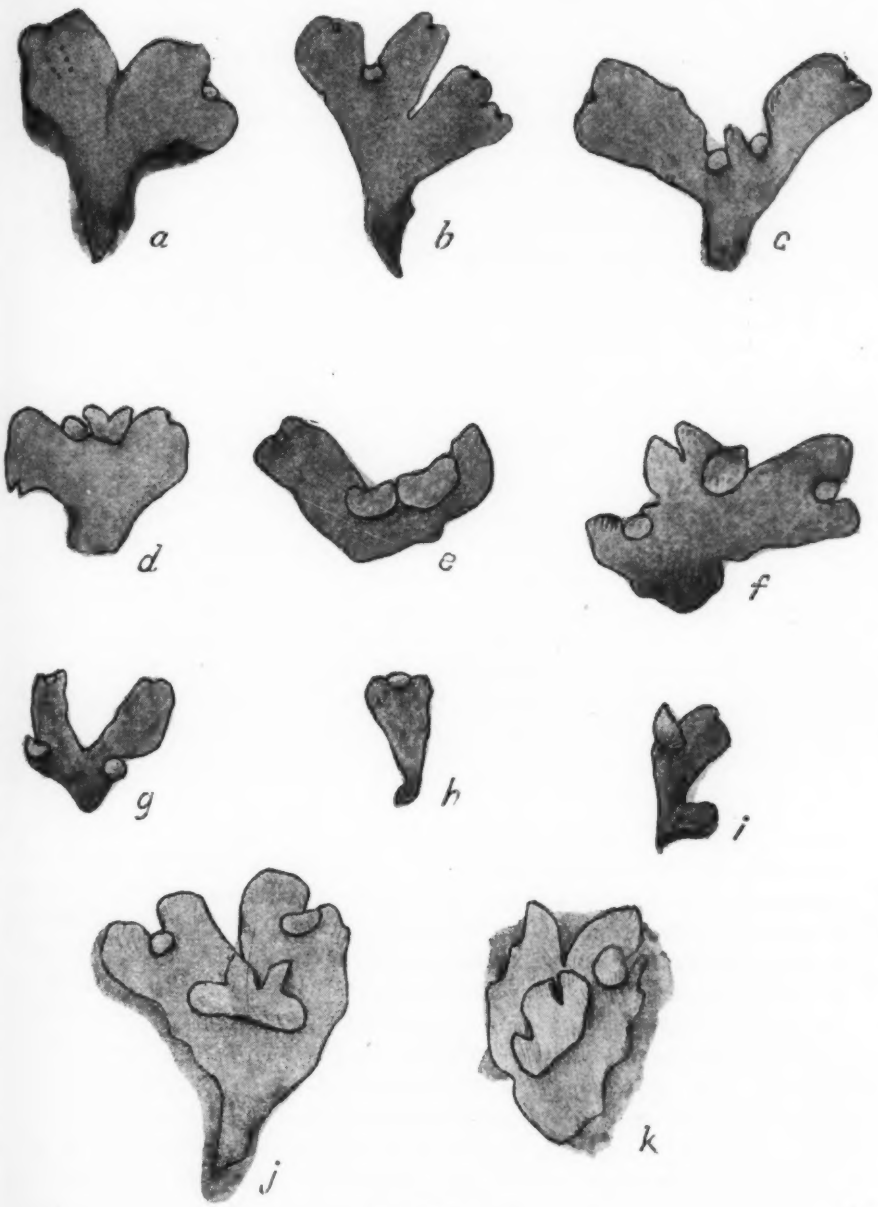
Aitchisoniella is one of those genera discovered and described by Prof. Kashyap, about which it is remarked, " The new genera are of extraordinary interest, and may be said to revolutionise the phylogeny of Marchantiales so beautifully do they fill up the gaps between the formerly known types." Owing to the many transitional characters which it presents a detailed investigation of this plant was undertaken by the writer at the suggestion of Prof. Kashyap.

The material for the present investigation was collected by the writer near Narkanda (9,000 ft.), Matiana (8,000 ft.) and Simla (7,000 ft.). The collections were made in the middle of July, 1933. Some more material was brought to the writer by Mr. Pran Nath Mehra from Dulchi Pass (6,000 ft.). The material was fixed in Bouin's fluid (Allen's modification), strong chrom acetic acid and formalin acetic alcohol. The sections were cut from 4–8 μ and stained with iron-alum hæmatoxylin, using 2 per cent. solution of Bismarck brown in 75 per cent. alcohol as a counter stain to bring out the cellulose cell walls. Delafield's hæmatoxylin was also used for the development of the sex organs and the growth of the thallus.

Gametophyte Body.

(*a*) *Vegetative.*

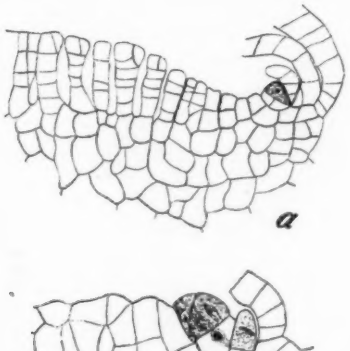
Thallus.—The gametophyte consists of a dichotomous or as remarked by Prof. Kashyap apparently pinnate thallus. The growing point divides once or twice and produces two to four regions of meristematic activity. The growth of these regions may or may not be uniform. If the growing point divides once and the two zones grow equally a plant with two similar lobes and showing dichotomy is produced (Text-Fig. I *a*), similarly by the equal activity of the secondary growing regions a plant is produced which shows typical dichotomy twice (Text-Fig. I *b*). The unequal activity of these regions results in various stages from a typical dichotomous plant to an apparently pinnate plant (Text-Fig. I *c–f*). The lobes are



TEXT-FIG. I.

about 4 mm. long and 2 mm. broad and are oblong ovate with a small depression at the apex. The dorsal surface of the thallus is perfectly smooth, no raised pores or arroles being visible. The plants have a light green or rather greyish colour. The ventral surface is hyaline or bluish. The midrib is thick and projects strongly below, and abruptly passes into the thin wings in the posterior part of the thallus, but near the apex the midrib gradually passes into the thin wings.

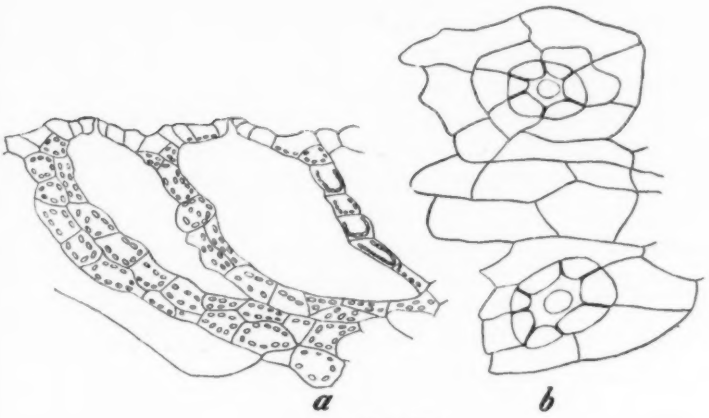
Growth of the thallus takes place by means of an apical cell (Text-Fig. II *a* and *b*), which cuts off segments on all the four sides as in the other Marchantiales.



TEXT-FIG. II.

Air Chambers.—As in the other Marchantiales except *Dumortiera* and *Monoclea*, the thallus shows the usual differentiation into the dorsal air-chamber region lying below the single-layered epidermis and the ventral compact parenchymatous region. The air chambers of *Aitchisoniella* belong to the *Marchantia* type. The chambers have no assimilating filaments and are in one layer except at the margin where they may be in two layers. The chambers are directed forwards and for this reason a transverse section reveals several layers of these, while a longitudinal section shows mostly a single layer. The chambers are separated from one another by septa which are one or two cells in thickness (Text-Fig. III *a*).

Scales.—The scales are arranged in two rows, one on either side of the midrib so that the latter is not covered by them. They are small, distinct, hyaline or bluish in colour and do not project beyond the margins. Each



TEXT-FIG. III.

scale is triangular or lunate and has an apical filamentous appendage of 3–5 cells. The cells of the young scales contain some chloroplasts. The terminal cell of the appendage contains mucilage and similar mucilage cells are also found projecting from the margins and a few such cells are even found in the body of the scale (Text-Fig. IV). Such mucilage cells have also been observed by Prof. Kashyap (1914) in the scales of *Plagiochasma appendiculatum* and *P. articulatum*. The appendages of the scales bend over the growing point and protect it. The scales are developed immediately behind the growing point. Immediately behind the latter, some of the ventral superficial cells grow outwards and forwards forming scales which are one cell thick.

Origin of Air Chambers.—In *Aitchisoniella*, the split occurs a few cells behind the apical cell at the surface (Text-Fig. II *a* and *b*) or just below it and proceeds inwards or outwards as the case may be. The writer's figures are highly suggestive of their schizogenous origin as stated by Barnes and Land (1907). The spaces thus formed become enlarged by lateral growth of the cells.

Pores.—The air chambers open on the outside by means of very minute pores (Text-Fig. III *a*). Each pore is surrounded by a single ring of 6 cells which have slightly thickened radial walls resembling the pores of Astroporæ (Text-Fig. III *b*). A thin membrane projects into the centre of the pore from the margin. The pores are simple and not much raised above the surface of the thallus. The cells forming the air pore margins are developed from the adjacent epidermal cells by segmentation.

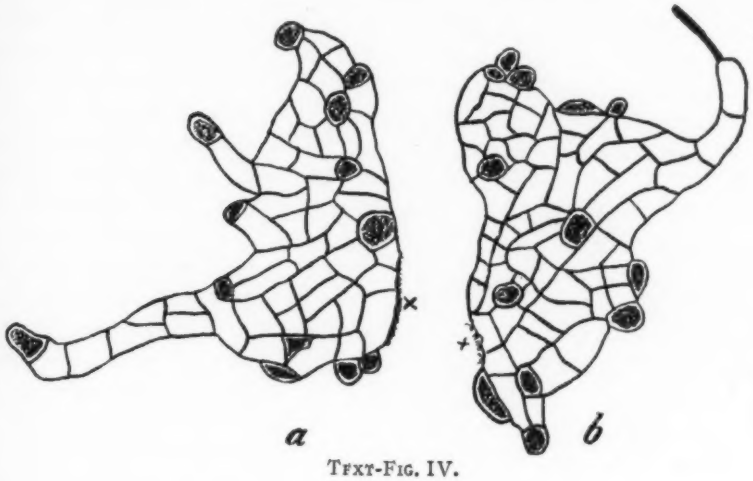
Ventral Tissue.—Below the layer of air-chambers lies the compact parenchymatous tissue. The cells of this compact part of the thallus contain numerous startch grains. In the older part of the thallus these cells are empty or contain small grains stained brown with iodine. The cells in this part occasionally contain fungal hyphæ. The fungus has been isolated and studied in culture by Dr. H. Chaudhuri (1935). Some of the cells of the lower-most layer become very large with dense contents and these develop into rhizoids.

Rhizoids.—Two kinds of rhizoids are found on the lower surface of the thallus some being smooth-walled while in others many peg-like thickenings project inwards. Each rhizoid is produced from a superficial cell with densely granular contents. This cell projects from the surface and grows enormously in length without any cell division.

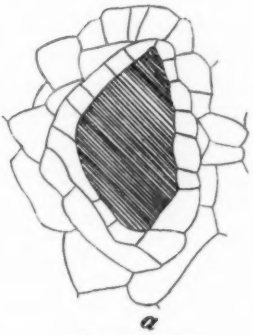
(*b*) *Sex Organs.*

Male Receptacle.—The plant is monœcious. The antheridia are produced in two rows embedded in the thallus behind the female receptacle (Text-Fig. I *a*). In the fresh plants the antheridia could not be made out clearly, but in properly fixed plants the antheridia are seen as round, white bodies inside the thallus. The antheridial chambers open on the outside by means of very minute papillæ.

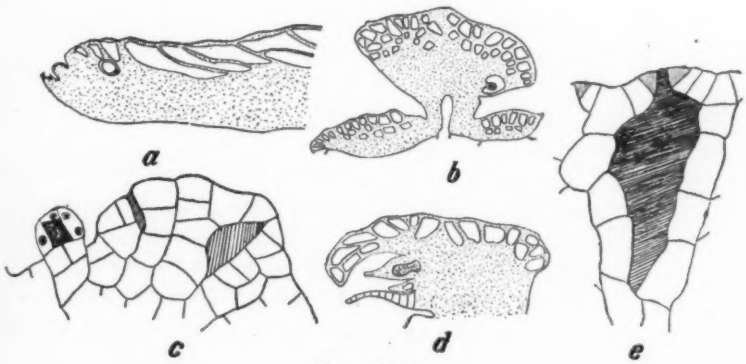
Antheridium Development.—The antheridium initial arises as a papillate cell (Text-Fig. VII, 1). It divides into two cells (Text-Fig. VII, 2), the upper forming the antheridium proper while the lower gives rise to the stalk. More transverse divisions occur in the upper cell (Text-Fig. VII, 3–5) resulting in a short filament of four cells (Text-Fig. VII, 6). This agrees closely with what Haupt (1921) has described for *Reboulia*, but differs from *Fimbriaria* as described by Campbell (1928) in which a row of six cells is produced before any vertical walls are formed. Vertical walls next appear first in the penultimate cell (Text-Fig. VII, 6 and 7) and later in the other cells dividing the filament into quadrants. After the vertical walls periclinal walls are formed (Text-Fig. VII, 10) which differentiate the wall of the antheridium from the primary spermatogenous cells. The basal cell divides a few times only by transverse and vertical walls forming a very short stalk. The divisions of the primary spermatogenous cells follow no regular plan. The wall is single layered in the mature antheridium and consists of very large hyaline cells (Text-Fig. V). The antheridium is an elongated structure lying in close contact with the cells of the thallus from which it is very difficult to separate (Text-Fig. V). The spermatozoid mother-cells do not present any peculiarity.



TEXT-FIG. IV.



TEXT-FIG. V.

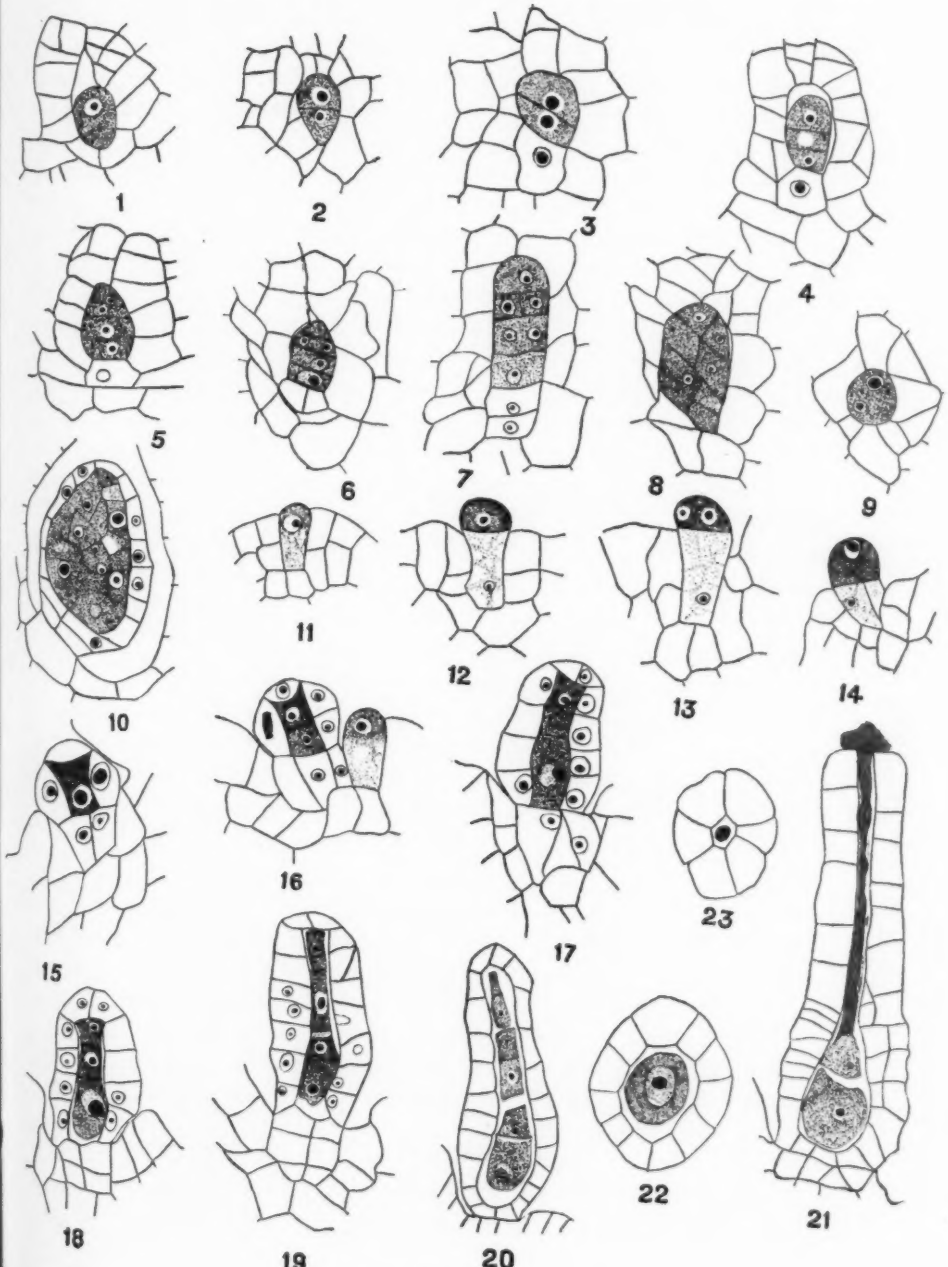


TEXT-FIG. VI.

Female Receptacle.—The archegonia are borne on a receptacle, which arises as a small hemispherical body at the end of a thallus lobe (Text-Fig. VI *a*). The main thallus forks once or twice before the formation of the receptacle. The female receptacle is variable in position, it may be terminal, lateral or in the fork between the two lobes (Text–Fig. I *b–i*). The receptacle normally has one or two involucres (Text-Fig. I *e–f*), but in some cases three or even four involucres were seen (Text-Fig. I *j–k*). As suggested by Kashyap, the plant shows much resemblance to the male receptacle of *Cyathodium tuberosum* in the position of the female receptacle and the variations in the number of involucres in each receptacle. The mature receptacle is subsessile and is attached to the thallus by a very small stalk like constriction which has a distinct groove (Text-Fig. VI *b*) and a few scales on the anterior side. The involucre in the mature state is ovate in outline and opens by a narrow circular mouth directed slightly upwards and forwards. The margins of the involucre are thin and hyaline and the ventral part is only a single layer of cells in thickness (Text-Fig. VI *d*). The receptacle has a single layer of dorsal air-chambers which are directed obliquely forward. The air-chambers open on the outside by means of pores which are not different from those found on the thallus (Text-Fig. VI *e*). The air chambers develop early in the development of the receptacle usually at the same time as the archegonia and they arise in a schizogenous manner described by Barnes and Land (1907) (Text-Fig. VI *e*).

Archegonium Development.—The archegonium initial arises as a superficial cell (Text-Fig. VII, 11), which becomes projected above the surface of the receptacle. It divides by a transverse wall at some distance above the level of the adjacent cells into an upper much smaller cell, which gives rise to the archegonium proper and the lower larger cell which forms the stalk (Text-Fig. VII, 12). The upper cell has much denser contents than the lower one. The upper cell divides by three vertical walls thus giving rise to a primary axial cell and three primary wall cells (Text-Fig. VII, 13 shows only one vertical wall). The basal cell then divides by a vertical wall and in one case this division was observed even before the appearance of the three vertical walls (Text-Fig. VII, 14).

In *Marchantia*, Strasburger (1869) has described that before the appearance of the three vertical walls the upper cell divides by a transverse wall into an upper and a lower cell of which the latter also contributes to the archegonium stalk, while the former develops into archegonium proper. Janeswky (1872) has given the same account for *Preissia quadrata*. In *Aitchisoniella*, however, this does not occur and the development is normal as in all the other Liverworts.



Text-Fig. VII.

The primary axial cell divides by a transverse wall into a small upper cell (cover cell) and a lower central cell (Text-Fig. VII, 15). The central cell by a transverse division gives rise to an upper primary neck canal cell and a lower primary ventral cell (Text-Fig. VII, 16). The three peripheral cells also divide by transverse walls. The primary neck canal cell divides into two neck canal cells and this division is accompanied by the formation of a vertical wall in the cover cell (Text-Fig. VII, 17, 18). The primary ventral cell next divides by a transverse wall into a ventral canal cell and an egg (Text-Fig. VII, 19). In the other Liverworts so far studied the primary neck canal cell divides into four before the division of the primary ventral cell. Durand (1908), however, has described premature division of the primary ventral cell in *Marchantia*. Miss Starr (1916) states that in *Aytonia* (= *Plagiochasma*) the primary neck canal cell divides into eight prior to the division of the primary ventral cell. The two neck canal cells divide by transverse walls into four neck canal cells (Text-Fig. VII, 20) and the number is not increased later as described by Haupt (1921) for *Reboulia*. As in the other Marchantiales the neck shows six cells in cross-section (Text-Fig. VII, 23). At maturity the neck of the archegonium is straight and about 92 μ in length.

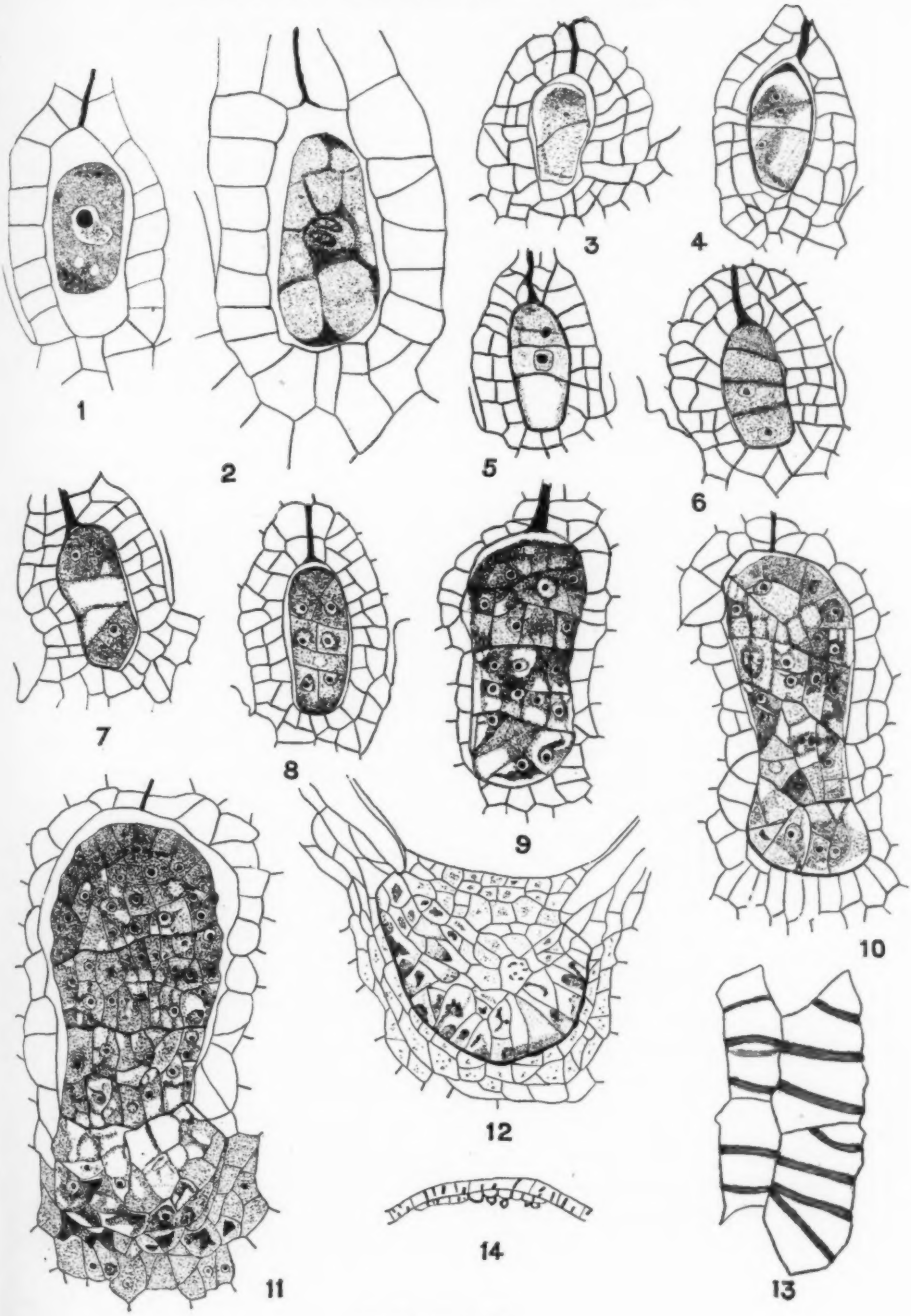
The wall of the archegonium is single-layered at the time of fertilization but afterwards it grows apace with the developing embryo and forms a four-layered calyptra.

Involucre.—The involucre does not arise as a stimulus of fertilization, as it was seen in many cases fully formed where the archegonia had remaind unfertilized. There are five or six archegonia in each involucre, but it usually contains only one ripe sporogonium, although two sporogonia are sometimes found in early stages of their development.

Fertilization.—The male nucleus was seen lying on the periphery of the female nucleus. This is shown in Text-Fig. VIII, 2 by dots because it was lying on the other side of the female nucleus and was seen only by changing the focus through it. In another case the male nucleus had just reached within the female nucleus, but the two had not lost their individuality. At this stage the male nucleus was decidedly smaller than the female nucleus. The chromatin of the male nucleus was uniform and deeply stained while that of the female was granular and faintly stained (Text-Fig. VIII, 1).

Sporophyte.

Embryo.—After fertilization the egg is divided by a transverse wall into nearly equal epibasal and hypobasal cells (Text-Fig. VIII, 3). The first wall



Text-Fig. VIII.

formed is much curved and oblique, but may be perpendicular to the longitudinal axis of the archegonium as is suggested by some of the later stages.

The epibasal cell next divides by a transverse wall which may be parallel to the first formed (Text-Fig. VIII, 5) or slightly inclined to it (Text-Fig. VIII, 4) resulting in a row of three cells. Later the hypobasal cell also divides by a transverse wall and at this stage the embryo consists of a row of four cells with nearly parallel walls (Text-Fig. VIII, 6). The sequence of wall formation is in agreement with what has been described for *Reboulia* by Dupler (1922) and Woodburn (1920), but differs from the account given by Haupt (1921) for *Reboulia* who states that the epibasal cell alone divides by two transverse walls.

The occurrence of a filamentous embryo in *Aitchisoniella* agrees with the embryo described by Haupt (1921), Woodburn (1920) and Dupler (1922) for *Reboulia* by O'Keefe (1915) for *Targionia*, by Lang (1905) for *Cyathodium cavernarum*, by Starr (1916) for *Aytonia*, by Meyer (1913) for *Plagiochasma* and by Campbell (1928) for *Geothallus* and *Sphærocarpus*.

The octant type of embryo has been described by Abrams (1899) for *Cryptomitrium*, by Anderson (1929) and Durand (1908) for *Marchantia*, by Campbell (1928) for *Targionia*, by Haupt (1926) for *Preissia*, by Lang (1905) for *Cyathodium fœtidissimum* and by Campbell (1928), Garber (1904), Lewis (1906) and Black (1913) for *Riccia*.

This shows that in the species of the same genus and even in the same species both the filamentous as well as the octant types of embryo are found. The presence of a filamentous embryo in an increasing number of Marchantiales makes it clear that octant type of embryo is not typical of this group in contrast with the filamentous type of Jungermanniales.

After the formation of a row of four cells, vertical walls begin to form. These first appear in the apical and the basal cells, and later in the middle cells also. The apical cell of the row of four divides by very oblique walls thus cutting off a triangular cell at the apex (Text-Fig. VIII, 7). In some cases the next wall is formed at an angle to the first formed thus producing an apical cell with two cutting faces, which very probably cuts off a few segments (Text-Fig. VIII, 8). Woodburn (1920) has shown the presence of a functional apical cell in *Reboulia*. Haupt (1921) claims that in *Reboulia* " a truly median section has never revealed the presence of an apical cell ". Dupler (1922) states that in *Reboulia* " the apical cell functions not more than a very few times being soon lost in the growing embryo where the apical function becomes distributed to a number of cells ". Although the triangular cell seen even in perfectly median sections at the apex of the

embryo in *Aitchisoniella* closely resembles the apical cell of *Reboulia* yet nothing positive could be stated about its functioning as a true apical cell until the plant is more thoroughly investigated.

The basal cell of the row of four divides by a vertical (Text-Fig. VIII, 8) or an oblique wall (Text-Fig. VIII, 7). When an oblique wall is formed it cuts off a triangular cell like the apical cell at the apex, but the rôle of this cell in contributing to the growth of the young sporophyte could not be ascertained with any certainty. The basal cell in *Aitchisoniella* forms the whole of the foot and does not remain merely as an appendage to the mature sporophyte as described by Dupler (1922) for *Reboulia*.

After the formation of the vertical wall more transverse divisions occur in the segments. These transverse divisions are followed by periclinal walls, which are especially abundant in the two epibasal cells and the one upper hypobasal cell (Text-Fig. VIII, 9, 10).

The origin of the different regions was studied with some exactness. The first transverse wall delimits the upper capsule region from the lower foot and seta region. The upper cell of the hypobasal region gives rise to seta while the lower forms the foot (Text-Fig. VIII, 9, 10). Text-Fig. VIII, 11 indicates this point. This agrees with the account of Dupler (1922) for *Reboulia* as far as the origin of the capsule is concerned. Dupler, however, states that the basal cell makes a relatively small contribution to the tissue of the sporophyte and nearly the whole of the foot and seta is derived from the upper of the two hypobasal cells. In *Reboulia* Woodburn (1920) and Haupt (1921) regard that the foot is formed from the hypobasal cell, while the capsule and seta are formed from the epibasal cell.

Young Sporophyte.—In the developing embryo the growth becomes unequal after sometime, the hypobasal region lagging behind and the epibasal developing more rapidly (Text-Fig. VIII, 11). In the basal portion of the embryo the growth is not wholly stopped and further growth results in the formation of a pretty well-developed foot. This difference in growth clearly marks off the capsule from the foot separated by a very short seta.

It is probable that the first periclinal walls delimit the capsule wall from the sporogenous tissue, although it does not show any physiological differentiation until later.

The foot is pretty well developed and assumes its bulbous form very early and its cells are densely granular and stain very deeply. The seta is very short being a mere constriction between the foot and the capsule (Text-Fig. VIII, 12).

After sometime the wall of the developing capsule loses its deeply stainable character and becomes physiologically differentiated from the sporogenous tissue. The sporogenous tissue later becomes differentiated into spore mother-cells and elaters. The spore mother-cells are not lobed and are 32 μ in diameter. They divide twice to form tetrade which separate at maturity forming the spores.

Mature Sporogonium.—The wall of the capsule consists of a single layer of cells, except at the apex where it is two-layered with short elater-like cells fixed to it, projecting below into the cavity of the capsule (Text-Fig. VIII, 14). Three or four short elaters are found fixed at the base of the capsule. Similar cells have been described by Prof. Kashyap (1914) in *Targionia* occurring both at the base and the apex of the capsule.

Prof. Kashyap (1914) has described a single-layered apical cap in *Aitchisoniella* with short elater-like cells attached to it. But in the writer's preparations the capsule wall was found to be two-layered at the apex but no conclusive statement could be made unless some more ripe sporogonia are examined.

The wall of the capsule is strengthened by annular and spiral thick bands as in *Targionia* (Text-Fig. VIII, 13).

The mature spores are 36 μ in diameter, tetrahedral and densely covered with round papillæ on the convex side. The elaters are fusiform, simple or branched, trispiral and on average 120 μ long.

Discussion.

Cavers (8) following Leitgeb divided the Marchantiales according to the following scheme :—

Marchantiales.

Ricciaceæ	..	*Riccia* (including *Ricciella*). *Ricciocarpus, Tesselina.*
Corsiniaceæ	..	*Bosehia* and *Corsinia.*
Monocleaceæ	..	Single genus *Monoclea.*
Targioniaceæ	..	*Targionia, Cyathodium.*
Marchantiaceæ	..	Rest of the Marchantiales.

1. Astroporæ.
2. Operculatæ.
3. Compositæ.

It is clear from the above scheme of classification that Targioniaceæ and Marchantiaceæ have been separated as two different families of equal rank. This separation is seriously challenged on the two grounds, namely,

(i) that the two genera are not so closely allied as they have been supposed to be hitherto and are rather widely separated. (ii) The presence of transitional types between the higher Marchantiales on the one hand and the genus *Targionia* on the other hand does not justify this separation. According to Deutsch (1912) the two genera have but the one salient feature which is common to them and them only, a single involucre enclosing a group of terminally borne archegonia and that such a character would not be sufficient to bind two genera differing so widely in all other respects into one family. The above suggestion of Deutsch is strengthened by the presence of dorsal involucres in some species of *Cyathodium* and the study of *Cyathodium tuberosum* by Kashyap (1914). The presence of a typical composite type male receptacles in *C. tuberosum* leaves no doubt that the two genera have different origins and the resemblances are a case of parallel evolution and not a result of monophyletic origin.

Exormotheca was regarded as the simplest member of the Compositæ. It was supposed to possess a simple type of male and female receptacles. The female receptacle consists of two involucres, the minimum number which could represent a branch system. In *Aitchisoniella* as already seen the receptacle normally bears one or two involucres. It resembles *Exormotheca* in the position of the female receptacle and the number of involucres. It also suggests some affinities with *Targionia* in having one involucre. Thus with regard to the number of involucres in the receptacle this genus stands as an intermediate form between *Exormotheca* on the one hand and *Targionia* on the other. It thus serves to a large extent to bridge over the gap between the Compositæ and the Targioniaceæ. This is further supported by many resemblances which they afford in their morphological features. Although the structure of the thallus in *Aitchisoniella* presents some similarity with the Astroporæ, the general development of the various organs, one involucre, group of archegonia in each involucre, the capsule wall and to a less extent the ventral scales at once suggest its affinities with *Targionia*. The resemblances of the genus *Aitchisoniella* with *Exormotheca* are also very striking and as Prof. Kashyap (1914, 1919) suggests "if the female receptacle of *Exormotheca* were to become sessile we should have a structure like the female receptacle of *Aitchisoniella* with the difference that the involucres in the latter are not directed so distinctly laterally as those of the former. But this difference can be easily explained by the absence of the peduncle, the small amount of the receptacle tissue and the stoppage of growth soon after dichotomy.

The male receptacle of *Cyathodium tuberosum* Kash. is very instructive as it suggests in a general way, how a simple receptacle of *Targionia* could

be derived from that of *Aitchisoniella*. The genus *Cyathodium* is believed by all to have suffered reduction and it is evident from the structure of its various organs. The male receptacle of *C. tuberosum* is very small and without distinct lobes when it is lateral or in the fork between the two vegetative lobes. When it is terminal, it is large distinctly lobed with a stalk-like constriction which has even a shallow groove on the anterior side. The receptacle thus represents a definite branch system and is of the type met within higher Marchantiales. According to Prof. Kashyap all the lobes in a male receptacle may bear antheridia or some lobes may not bear antheridia and become vegetative. In the former case the receptacle is terminal, large and of a composite type, but in the latter case the receptacle is small and lies either on the side of a large vegetative lobe or in the fork between two vegetative lobes. This we also find in *Exormotheca*, but the number of reproductive branches has become permanently fixed to two. In *Aitchisoniella* the number of female reproductive shoots is not fixed and varies between one and two. This is also supported by the finding of three and even four involucres in some plants of *Aitchisoniella* as we have already seen. Finally in *Targionia* the number is again fixed to one.

Thus we can see the actual reduction of the composite male receptacle into a simple type by the transformation of some of the branches into vegetative shoots and the slight development of the rest so that the receptacle does not show any lobes. Indeed according to the view of evolution by reduction as suggested by Prof. Kashyap " the guiding principle in the evolution of the living Marchantiales has been to increase the amount of vegetative tissue at the expense of the sexual organs and the sporophyte ".

If the male receptacle of *Cyathodium tuberosum* can thus be reduced from a composite type to a simple type and that again to a mere cushion on ordinary vegetative shoot as in *Targionia*, surely the female receptacle can also undergo the same transformation especially when we find an intermediate form like *Aitchisoniella* between *Exormotheca* and *Targionia*, and various positions of the involucre in some species of *Cyathodium* from typically sub-apical to a typically dorsal position.

Conclusions.

In the light of the present investigation *Exormotheca* can no longer be regarded as the lowest type of the Compositæ as *Aitchisoniella* breaks down the boundary line existing between Compositæ and Targioniaceæ making the one pass insensibly into the other. Thus the two families should be merged into the family Marchantiaceæ as has already been suggested by Prof. Kashyap.

Summary.

1. The genus *Aitchisoniella* is monotypic and occurs only in India. It is monœcious.

2. The growth of the thallus takes place by means of a single apical cell which cuts off segments on all the four sides.

3. Air-chambers are empty, in one layer, and directed forwards. Their origin is schizogenous.

4. The development of the antheridium follows the usual Marchantiaceous type. Vertical wall formation begins after a filament of four cells is produced.

5. The female receptacle may be terminal, lateral, or in the fork between the two lobes. It bears normally one or two involucres, but plants are found bearing three or four involucres.

6. In the female receptacle there is a dorsal layer of air-chambers, which are obliquely directed forwards and open to the outside by means of simple pores. Their origin is schizogenous as in the thallus.

7. The first division of the fertilized egg may be transverse or oblique.

8. A filamentous embryo results by the formation of transverse divisions both in the epibasal and the hypobasal cells. This is followed by vertical walls in all the four cells.

9. At the apex of the young capsule a triangular cell is cut off, but its functioning as a true apical cell is not definitely known.

In the end, the writer wishes to express his sincere thanks to the late Prof. S. R. Kashyap for stimulating suggestions and criticisms during the course of the investigation.

LITERATURE CITED.

1. Abrams, L. R. .. "Structure and development of *Cryptomitrium tenerum*," *Bot. Gaz.*, 1899, **37**, 110–121.

2. Anderson, E. N. .. "Morphology of the sporophyte of *Marchantia domigensis*," *ibid.*, 1929, **87**, 150–164.

3. Barnes, C. R., and Land, W. J. "The Origin of Air-chambers," *ibid.*, 1907, **44**, 189–197. 189–197.

4. Black, C. A. .. "The Morphology of *Riccia frostcii*," *Ann. Bot.*, 1913, **27**, 511–532.

5. Campbell, D. H. .. *The Structure and Development of Mosses and Ferns*, New York, 1928.

6. Cavers, F. .. "Interrelationship of Bryophyta," *New Phyt.*, 1912.

7. Chaudhuri, H. .. "Studies in the physiology of the fungal endophytes of certain Indian Liverworts," *Ann. Bryol.*, 1935, **8**, 47–56.

8. Deutsch, H. D. .. "A study of *Targionia hypophylla*," *Bot. Gaz.*, 1912, **53**, 492–503.

9. Dupler, A. W. .. "Early embryology of *Reboulia hemispherico*," *ibid.*, 192?, **74**, 143–156.

10. Durand, E. J. .. "The development of sexual organs and sporogonium of *Marchantia polymorpha*," *Bull. Torrey. Bot. Club*, 1908, **35**, 321–335.

11. Garber, J. F. .. "The life-history of *Ricciocarpus natans*," *Bot. Gaz.*, 1904, **37**, 161–177.

12. Haupt, A. W. .. "Morphology of *Preissia quadrata*," *ibid.*, 1926, **82**, 31–51.

13. ———— .. "The gametophyte and sex organs of *Reboulia hemispherica*," *ibid.*, 1921, **71**, 61–74.

14. ———— .. "Embryogeny and sporogenesis in *Reboulia hemispherica*," *ibid.*, 1921, **81**, 446–453.

15.* Janczewski, ed. von .. "Vergleichende untersuchunglu ubder die Ent wilk lungsgeschichte des Archegoniums," *Bot. Zeit.*, 1872, **30**, 386–389.

16. Kashyap, S. R. .. "Morphological and biological notes on the new and little known liverworts. I," *New Phyt.*, 1914, **13**, 206–226; II, *New Phyt.*, 1914, **13**, 308–323.

17. ———— .. "The relationships of liverworts especially in the light of some recently discovered Himalayan forms," *Proc. Asiatic Soc. Bengal*, 1919, **15**, No. **4**.

18. Lang, W. H. .. "On the morphology of *Cyathodium*," *Ann. Bot.*, 1905, **19**, 411–426.

19. Lewis .. "The embryology and development of *Riccia lutescence* and *Riccia crystallina*," *Bot. Gaz.*, 1906, **42**.

20. Meyer, K. .. *Unterschungen uber den sporophytder Lebermoose*, 1913, Part II.

21. O'Keefe, L. .. "Structure and development of *Tarionia hypophylla*," *New Phyt.*, 1915, **14**.

22. Starr, A. M. .. "A Mexican Aytonia," *Bot. Gaz.*, 1916, **61**, 48–58.

23.* Strasburger, E. .. "Die Geschlechtsorgane und die Befruchtung bei *Marchantia polymorpha* L.," *Jahrb. Wiss Bot.*, 1869–1870. 1870, **7**, 409–422.

24. Woodburn, W. L. .. "Preliminary notes on the Embryology of *Reboulia hemi spherica*," *Bull. Torrey. Bot. Club*, 1920, (?), 461-464.

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* Indicates that the original paper has not been seen by the writer.

EXPLANATION OF TEXT-FIGURES.

TEXT-FIGURE I.

(*a*) A plant showing antheridial papillæ. × 6.

(*b-i*) Plants showing various forms of branching and positions of the female receptacle. × 6.

(*j, k*) Plants showing 4 and 3 involucres in a receptacle. × 6.

TEXT-FIGURE II.

(*a*) V.L.S. thallus showing the development of air-chambers. × 300.

(*b*) V.L.S. thallus showing the apical cell. × 300.

TEXT-FIGURE III.

(*a*) V.L.S. Thallus (a portion) showing two air-chambers and pores. × 170.

(*b*) Two pores as seen from above. × 300.

TEXT-FIGURE IV.

Two scales. × 120.

TEXT-FIGURE V.

A mature antheridium. × 260.

TEXT-FIGURE VI.

(*a*) V.L.S. thallus showing a young female receptacle at the anterior end. × 37.

(*b*) T.S. thallus with female receptacle showing stalk-like constriction and the groove. × 25.

(*c*) Portion of a female receptacle, showing the development of air chambers. × 450

(*d*) V.L.S. female receptacle showing involucre. × 37.

(*e*) An air chamber and a pore of the female receptacle in Longitudinal section. × 250.

TEXT-FIGURE VII.

FIGURES 1–10.—*Stages in the development of antheridium.*

1. Antheridium initial. × 600.
2. First division of the same into basal and outer cell. × 600.
3–5. Division of the outer cell to form a filament of four. × 600.
6–8. Formation of vertical walls. × 600.
9. Antheridium in a transverse section. × 600.
10. Differentiation of antheridium wall from the central spermatogenous cells. × 600.

FIGURES 11–21.—*Stages in the development of archegonium.*

11. Archegonium initial. × 600.
12. Formation of stalk cell from archegonium proper. × 600.
13. Formation of vertical wall in the archegonium proper. × 600.
14. Formation of a vertical wall in the stalk cell. × 600.
15. Formation of cover celf and central cell from the axial cell and division of the stalk cell. × 600.
16. Formation of primary neck canal cell and ventral cell from the central cell. × 600.
17–18. Division of primary neck canal cell to form two neck canal cells and formation of vertical wall in the cover. × 550.

19. Division of the ventral cell into ventral canal cell and egg. × 550.
20. Division of the two neck canal cells to four neck canal cells.
21. Mature archegonium. × 500.
22. T.S. of venter with egg. × 600.
23. T.S. neck of archegonium. × 600.

TEXT-FIGURE VIII.

FIGURES 1–14.—*Stages in the development of sporophyte.*

1. Male and female nuclei in contact. × 800.
2. Male nucleus (represented with dots) lying on the periphery of the female nucleus. × 800.
3. Showing the first division wall. × 350.
4. Showing the epibasal cell divided by an oblique wall. × 350.
5. Showing the epibasal cell divided by a wall parallel to the first. × 350.
6. Showing the typical filamentous embryo. × 350.
7. Showing the oblique vertical walls in the apical and the basal cells. × 350.
8. Showing more vertical walls in the cells. × 350.
9, 10. Showing the more vertical and transverse walls, and development of the foot seta and capsule from different regions. × 350.
11. Showing the capsule wall clearly differentiated from the sporogenous tissue. × 350.
12. Showing the foot and seta. × 220.
13. Showing the thickening bands of the capsule wall. × 350.
14. Showing the apical portion of the capsule with elater like cells attached to it. × 70.

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ERRATA.

Volume VII, No. 3, March 1938.

(1) P. 111, line 23, *for* " seriatum " *read* " seriatim ".

(2) Pp. 118 and 119, in Table I

Under 1935–36 :

Col.	*Variety or Hybrid*	*for*	*read*
2	A	33·3	25·6
6	A	10·7	7·5
1	B	18·3	18·9
2	B	43·0	34·2
6	B	13·5	13·6

Under 1936–37 (Second Sowing) :

3	A	25·1	35·1

Under 1936–37 (Fourth Sowing) :

4	B	12·8	13·8
6	B	8·6	9·4
9	B	7·8	8·3

STUDIES IN BLOOD SUGAR.

I. Variation of Blood Sugar during Menstrual Cycle.

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and
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Received April 9, 1938.

While variations of blood sugar of human individuals with age, diet, exercise, emotion, diseases, and influence of drugs have been studied, a survey of the literature available to us does not show many references to the variation of blood sugar during the menstrual cycle of women. Okey and Robb (1925) in their "Studies of the Metabolism of Women" state that there seems to be no ground for conclusion that there is a consistent cyclic variation in fasting blood sugar level of women. Dionne and Arenstam (1930) have studied the blood sugar fluctuations in women over a period of 24 hours under basal conditions and obtained for the normal fasting value 90–100 mgms. per cent.

The present investigation was undertaken to find out if there was any consistent variation from day to day in the blood sugar of women especially during the menstrual cycle. Incidentally, their fasting blood sugar was also estimated. The subjects were selected from among the students of the College. The blood sugar of some of them was determined daily for a period of 25 to 31 days in order to arrive at an average for the individual. Table I gives these results. It is seen from Table I that there is a distinct rise in the blood sugar on the day of the onset of the menstrual flow and then there is a fall almost to the fasting level and then a rise to the normal. A few typical curves are drawn to show the variations distinctly. Table II embodies the results of the determinations done a few days prior to the probable onset of menstruation. The rise is observable here as well. Table III gives the results of the determinations carried out with the same individual for two consecutive menstrual periods to verify if the results were real or casual. It confirms the previous observations. Besides the rise on the day of menstruation there are two or more definite rises in the curve when the record is made continuously for about a month. These rises do not occur

B1 F

TABLE I.

Mgms. of Blood Sugar in 100 *c.c. of Blood.*

Days	Subject						
	No. 1 S	No. 2 L	No. 3 C	No. 4 G	No. 5 K	No. 6 KL	No. 7 D
1	81	86	82	72	86	86	94
2	86	77	77	77	82	82	93
3	92	86	82	79	77	81	90
4	82	87	104	74	82	97*	118*
5	81	77†	81†	77†	99	95	86
6	81	82	87	77	102	81	90
7	79	86	90	81	87	82	86
8	81	82	86	79	86	86	93
9	77†	82	90	82	86		90†
10	86	82	90	81	86		90
11	87	99	90	79	86	90	110
12	87	82	120*	79	82†	86	110
13	94	79	82	86	86	86	90
14	87	81	90	87	82	82	90
15	87	87	86	77	82	87	87
16	86	108	86	77	90	86	90
17	82	82	82	79	86	86	90
18	86	81	82	79	99*	90	94
19	82	81	82	74	87	81†	94
20	86	82	82	81	90	86	93
21	86	108*	81	93*	90	86	90
22	81	79	90	77	87	86	93
23	82	79	86	79	86	87	93

* Menstruation. † Fasting.

TABLE I—(*Contd.*)

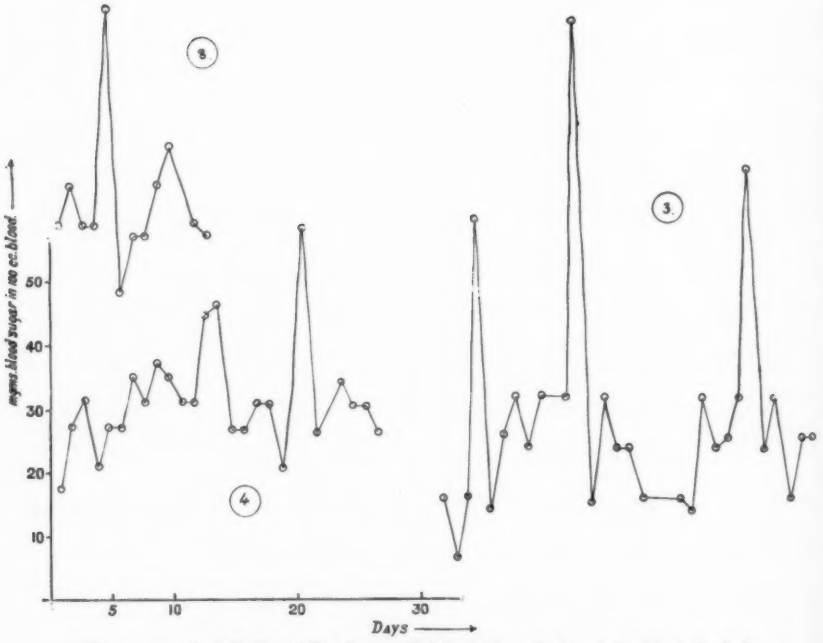
Days		Subject						
		No. 1 S	No. 2 L	No. 3 C	No. 4 G	No. 5. K	No. 6 KL	No. 7 D
24		82	82	87	81	92	82	93
25		97*	86	90	79	86	82	93
26		77	81	108	79	86	86	
27		77	82	86	77		90	
28		82	82	90			86	
29		86	82	82				
30		82	86	87				
31		86		87				
Average	..	84	84	87	80	87	86	93
Range lowest	..	77	77	77	77	77	81	86
Range highest	..	97	108	120	93	102	97	118

TABLE II.

Days	Subject						
	No. 1 S	No. 2 L	No. 3 C	No. 6 KL	No. 7 D	No. 8 J	No. 9 J′
1	86	86	81	86	92	90	77
2	87	87	81	92	92	86	86
3	102*	81	82	81	87	93	79
4	95	77	99*	81	104*	93	79
5	82	86	82	92*	86	87	did not come up
6	86	86	81	81	87	111*	
7	86	86	82	81	87	86	
8	86	81		81	92	87	
9						81	

TABLE III.
Subject No. 8 J

Days	First period	Second period
1	90	87
2	86	90
3	93	87
4	93	87
5	87	104*
6	111*	82
7	86	86
8	87	86
9	81	90



Curves marked 3, 4 and 8 refer to Subject Nos. 3, 4 and 8 (First Period).

in any definite relation to the menstrual rise but their frequency suggests something more than mere coincidence or errors in not observing the conditions rigorously. Further investigation is in progress.

Experimental.

The subjects selected were nine healthy South Indian women students of the College, who had all normal menstrual history. Their ages varied from 18 to 27 years. The nine students were divided into two groups, A and B. Group A consisted of seven students whose blood sugar was determined daily for 25 to 31 days. Group B consisted of seven students, five from Group A and two others. These students were asked to come up for experiment two to five days prior to the probable onset of menstruation. The blood sugar was determined for about 8 days continuously in all at the end of which it reached normal to the individual.

The blood was taken each day 4 to 4½ hours after food in order to avoid variations of blood sugar after meals ; they were not allowed to eat or drink during the interval. The food taken was the normal South Indian food, not subject to much variations. They were allowed to rest for ½ hour before drawing out blood for analysis. Capillary blood was used for the experiment and was got by pricking the fingers, 0·2 c.c. being used for each estimation. The samples were analysed immediately. MacLean's method was used throughout, taking all precautions to minimise the experimental errors. In all cases the interval between the onset of menstruation and determination of blood sugar did not exceed eight hours.

We wish to record here our thanks to the women students of the Medical College without whose willing co-operation this investigation would not have been possible.

Summary.

1. The blood sugar of seven South Indian women students has been determined daily for about a month. The average for each individual varies from 80 to 93 mgms. per 100 c.c. of blood. During the menstrual period a rise and fall in blood sugar is noticed.

2. The fasting blood sugar for these students varied from 77 to 90 mgms. per 100 c.c. of blood, the average being 81 mgms. per cent.

REFERENCES.

Dionne and Arenstam .. *J. Biol. Chem.*, 1930, **87**, 395.
Okey and Robb .. *Ibid.*, 1925, **65**, 165.

STUDIES IN BLOOD SUGAR.

II. Fasting Blood Sugar of South Indian Students in Mysore.

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Received April 9, 1938.

The fasting value of blood sugar of human individuals according to various authors varies from 60 to 120 mgms. per 100 c.c. of blood. Graham mentions that the blood sugar varies in health from 80 to 120 mgms. per cent. Tice states that the values that may be regarded as normal are 120 mgms. or less of glucose after fasting. Gray (1923) has found from an investigation of 421 cases the average percentage of blood sugar to be 90 mgms., the minimum being 40 and the maximum 160. MacLean has stated that a few hours after food, generally speaking, the blood sugar lies between 90 and 110 mgms. per cent. and the round figure of 100 is generally accepted as normal for average individuals. These figures do not refer to Indians, differences in values are varied and may be due to the method adopted for the estimation of sugar. Bhatia (1931) from an investigation of 60 subjects, making use of MacLean's method for 0·2 c.c. of blood, has deduced that the average fasting blood sugar of Indians is 117 mgms. per cent., that for vegetarians being 125, and for non-vegetarians 107 mgms. per cent. This author makes a reference to the work of McCay, Banerjee, Ghosal and Dutta who have found out the average blood sugar of Bengalis in normal health to be 130 mgms., a result borne out by the work of Brahmachari and Sen.

The values given above for Indians refer mostly to the residents of upper India. We have attempted here to find out the values for South Indian students in Mysore at different age periods. Students of the Mysore Medical College were chosen as the subjects. 107 healthy male students between the ages of 17 and 30 years willingly offered themselves for examination adhering to the restrictions imposed on them. They used to have dinner at 8 P.M. and come to the laboratory the next morning at 8 o'clock on an empty stomach. They refrained from any active exercise, such as swimming or tennis in the morning on the day of the experiment. On coming to the laboratory they were made to rest for about ½ hour. The habitual smokers of the group abstained themselves from smoking. Capillary blood was taken and the sugar estimated by MacLean's method. The results are set down in Table I.

TABLE I.

Mgms. of Blood Sugar in 100 c.c. of Blood.

Vegetarians.

S. Number	Age	Blood Sugar	S. Number	Age	Blood Sugar
1	18	94	26	19	72
2	21	81	27	21	81
3	24	72	28	23	72
4	20	81	29	23	70
5	18	81	30	21	72
6	20	81	32	22	74
7	19	74	34	21	81
8	21	72	35	19	72
10	19	81	36	23	72
11	23	81	38	21	72
12	18	81	39	20	72
13	19	72	40	21	72
14	19	67	41	19	81
15	22	72	42	19	86
16	19	72	43	23	70
18	18	86	44	22	72
19	21	77	45	23	72
20	19	86	47	24	80
21	19	72	49	25	74
22	23	77	50	22	74
23	26	72	51	24	74
24	22	81	52	21	74
*25	29	77	53	22	72

TABLE I—(*Contd.*)

S. Number	Age	Blood Sugar	S. Number	Age	Blood Sugar
54	19	82	79	25	91
55	25	77	80	22	81
56	24	81	81	24	72
57	21	81	*82	28	81
58	22	67	83	29	81
*59	22	74	84	24	91
60	24	74	85	26	81
61	22	72	86	26	72
62	23	91	87	25	77
64	20	77	*88	30	118
65	19	91	*89	26	81
66	21	86	90	23	79
67	24	91	*91	24	77
*68	26	77	92	25	81
69	25	81	93	28	72
70	20	86	*94	24	81
*71	28	77	95	25	77
73	23	81	96	24	91
74	24	81	*97	25	77
75	22	91	98	25	72
76	23	112	99	25	81
*77	22	72	*100	23	91
*78	28	81	*103	30	91

TABLE I—(*Contd.*)

S. Number	Age	Blood Sugar	S. Number	Age	Blood Sugar
Non-Vegetarians.			*63	24	72
9	19	70	*72	25	72
*17	20	72	*101	24	74
31	22	67	*102	26	81
*33	23	72	*104	30	81
*37	22	74	*105	23	81
46	20	70	106	20	77
48	27	70	107	20	81

* Smokers.

The average blood sugar of 107 students is 78 mgms. per cent. the lowest value being 67 and the highest 118 mgms. per cent. Of these 15 were non-vegetarians habituated to take mutton, fish and eggs daily. The average for this group is 75 mgms. per cent. The remaining 92 were 'vegetarians' whose diet consisted of rice, dhal, vegetables, milk and milk products ; the average for this group is 82 mgms. per cent. The vegetarians seem to have a higher fasting blood sugar than non-vegetarians as is mentioned by Bhatia (1931), but the blood sugar of either group in the state of metabolic rest, as obtained by us, is lower than that of Bhatia.

Table II gives the values for different age periods. There is not much difference in the value between the ages of 15 and 24 years, but between 25 and 30, a slightly higher value is obtained.

TABLE II.

Age	No. of Subjects	Blood Sugar Value mgms. in 100 c.c.
Below 20	18	78
20 to 24	62	78
25 to 30	27	89

There were 22 smokers and we were not able to detect any appreciable difference in the value of blood sugar between habitual smokers and non-smokers, as the average for them works out round about 78. (Dill, Edwards, 1934.)

We wish to express here our thanks to the students who willingly co-operated with us in this investigation.

Summary.

The fasting blood sugar of 107 students belonging to South India has been determined. The average value is found to be 78 mgms. per 100 c.c. of blood.

REFERENCES.

Bhatia .. *Half-yearly J. Mys. Univ.*, 1931, **5**, 5.
Dill, Edwards, etc. .. *Amer. J. Physiol.*, 1934, **109**, 118.
Graham .. *Text-book of Medicine*, 1933, 429.
Gray .. *Arch. Int. Med.*, 1923, **31**, 24.
MacLean .. *Monograph on Blood Sugar.*
Tice .. *Practice of Medicine*, **9**, 74.

STUDIES IN BLOOD SUGAR.

III. Blood Sugar of Children.

By C. Srikantia and D. Shamanna.

(From the Department of Physiology and Biochemistry, University Medical College, Mysore.)

Received April 9, 1938.

Britton (1930) has found that in cats in the later stages of pregnancy the fœtal blood sugar is lower than that of the mother. This fact has been demonstrated by Synder and Hoskins (1929) in the rabbit and by Corey in the rat. They further state that nearterm the fœtal blood sugar practically approaches the maternal. Holman and Mathieu (1934) have observed that the blood sugar of the new born infant is approximately equal to that of the mother, the mother having 100·5 mgms. per cent. and the infant 95·4 mgms. per cent. In infants of 4 to 9 months old, Lindberg found an average normal blood sugar of 117 mgms. per cent. (Peters and Van Slyke, 1931).

We undertook this investigation in order to arrive at a value for the South Indian children living in Mysore. It is needless to record here the difficulties in getting the children to the laboratory for the purposes of experiment. More than the children the parents have to be persuaded.

However 71 children aged four years and below, were chosen for the experiment. The children were healthy and belonged to the labour class. All the children except four were weaned. The blood sugar determinations were made in the morning before the children had any feed. They were brought to the laboratory, made to rest for about ½ hour before drawing out the blood. During the pricking they were kept as cheerful as possible, all excitement being avoided. Capillary blood was used and the sugar determined by MacLean's method. The values are given in Table I and they refer practically to the fasting level.

The diet of the children varied from milk to milk and rice, or ragi and rice. From Table I it will be seen that Nos. 1 to 7 were fed on milk, Nos. 8 to 21 had milk and rice and the rest ragi and rice with the ordinary vegetables and milk products. The average value of blood sugar works out to be

TABLE I.

No.	Age	Blood Sugar in mgms. %	Diet	No.	Age	Blood Sugar in mgms. %	Diet
1	2	70	Milk	23	3	77	Ragi & rice
2	2½	70		24	3	72	
3	1¾	72		25	2½	91	
4	2	74		26	4	79	
5	2	63		27	3	72	
6	1½	77		28	3¾	77	
7	1¾	74		29	3	74	
8	2½	72	Milk & rice	30	2½	48	
9	2	48		31	3½	77	
10	2	70		32	3	63	
11	1¾	63		33	3½	77	
12	2	70		34	4	82	
13	2	63		35	3¼	72	
14	2	74		36	2¾	100	
15	2½	77		37	4	77	
16	3	77		38	4	72	
17	2	86		39	3	77	
18	2	74		40	2½	77	
19	1¾	70		*41	3	79	
*20	1¾	100		42	4	77	
21	2	77		43	3	72	
22	3	81	Ragi & rice	44	3	74	

* Not weaned.

TABLE I—(*Contd.*)

No.	Age	Blood Sugar in mgms. %	Diet	No.	Age	Blood Sugar in mgms. %	Diet
45	3	70	Ragi & rice	*59	1¼	74	Ragi & rice
46	3	96		*60	2	81	
47	3	81		61	3½	70	
48	3	77		62	2½	77	
49	4	77		63	3¼	77	
50	3	77		64	2	70	
51	3	74		65	2½	63	
52	2	77		66	3	72	
53	4	74		67	3	74	
54	3½	67		68	3	70	
55	3	72		69	2¾	63	
56	4	74		70	2	63	
57	4	79		71	1¾	67	
58	3½	77					

73·8 mgms. per cent., the lowest being 48 and the highest 100 mgms. per cent. Though the foods were different, there seems to be very little variation in the blood sugar value.

Table II gives the values of blood sugar arranged according to ages. There is a slight but gradual increase in the average value but further work is to be done to arrive at a definite conclusion.

TABLE II.

Age	No. of Subjects	Blood Sugar
Below 2 years ..	7	71 mgms.
From 2 to 3 years ..	47	74 ,,
From 3 to 4 years ..	17	75·6 ,,

Summary.

The fasting blood sugar of 71 children between the ages of $1\frac{1}{4}$ and 4 years has been determined. The average value is in round figures 74 mgms. per 100 c.c. of blood.

REFERENCES.

Britton .. *Amer. J. Physiol.*, 1930, **95**, 183.
Holman and Mathieu .. *Amer. J. Obst. Gynec.*, 1934, **27**, 98.
Peters and Van Slyke .. *Quantitative Clinical Chemistry*, 1931 Ed., **1**, 108.
Synder and Hoskins .. *Proc. Soc. Expt. Biol. & Med.*, 1929, **26**, 804 (Britton).

NOTES ON INDIAN HEPATICS.

I. South India.

By R. S. Chopra, M.Sc.

(From the Botany Department, Panjab University, Lahore.)

Received March 7, 1938.

[Communicated by Dr. H. Chaudhuri, D.Sc. (London).]

Collections of Liverworts from South India have been coming into our Herbarium from time to time. An examination of these shows three new species and several new records; and thus warrants publication. Thanks are due to Rev. Father Foreau, Prof. Fyson, Prof. Iyengar, the late Prof. Kashyap, Prof. Rangachariar, Mrs. Robinson, Father Rupinat, Prof. Sampathkumaran and Mr. Sedgwick, whose collections have provided material for this note, and to Dr. Fr. Verdoorn for the determination of some of the Lejeuneaceæ.

RICCIACEÆ.

Riccia L.

R. himalayensis St. (1 : 93).

Tinnevelly Hills, Rangachariar, Bh. 1 (4*a*);
Negapatam, Mr. Robinson, 1928–29, 594, 595, 622–28;
Ramnad District, Foreau, 1935, 117.

R. cruciata Kashyap (1 : 95).

Travancore, Krupp, 1924, Bh. 1 (5*a*).

R. Frostii Aust. (4 : 42).

Anakapalle, Rangachariar, 1916, Bh. 1 (1*a*).

R. fluitans L. (1 : 97).

Madras, Iyengar, 1922, Bh. 1 (3*b*);
do. Chopra, 1929, 490;
Mahableshwar, D. Almeida, 1923, Bh. 1 (3*e*);
Panchgni, Blatter, 1928, 549, 562, 563.

R. sp. near *R. himalayensis* St.

Berhampur, Fyson, 1924, Bh. 1 (x*e*).

MARCHANTIACEÆ.

Targionia L.

T. hypophylla L. (1 : 57).
Madras, Iyengar, Bh. 7 (1*a*) ;
Mysore, Kashyap, 1907, 25.

Cyathodium Kunze.

C. tuberosum Kash. (1 : 53).
Mahableshwar, Sedgwick, 1919, 126.

C. aureonitens (Griff.) Schiffin. (4 : 63).
Konkan, Malabarhill, Bombay, Schiffner, 1895, Hepaticæ, Selectæ et Criticæ, No. 188.

C. sp.
Madras, Iyengar, 1922, Bh. 8 (x*a*, x*b*, x*c*).

This species in the position of the female involucre and the spores forms transition between *C. aureonitens* (Griff.) Schiffin. and *C. tuberosum* Kash. The two species are identical as has already been suggested by Prof. Kashyap.

Plagiochasma L. et L.

P. simlensis Kash. (1 : 79).
Mahableshwar, E. Blatter, 1929, 957 ;
Kodaikanal, Rangachariar, 1916, Bh. 12 (4, 4*a*) ;
Negapatam, Mrs. Robinson, 1928, 960.

P. appendiculatum L. et L. (1 : 76).
Nilgiris, Rangachariar, 1916, Bh. 12 (1*c*) ;
Mahableshwar, Sedgwick, 1919, 127.

P articulatum Kash. (1 : 75).
Ootacamund, Rangachariar, Bh. 12 (2*e*) ;
Ooty Road, Sedgwick, 42 ;
Mahableshwar, Blatter, 1928, 522 ;
Panchgni, Blatter, 1928, 522, 547, 557, 565.

P. nepalense (L. et Bisch.) St. (4 : 81).
Tinnevelly Hills, Rangachariar, 1916, Bh. 12 (4) ;
Hosur (Salem District), Rangachariar, 1916, Bh. 12 (4*a*).

Reboulia Raddi.

R. hemispherica (L.) Raddi. (1 : 72).
Nilgiris, Rangachariar, 1916, Bh. 13 (1*d*) ;
Madras, Iyengar, 1922, Bh. 13 (1*e*-1*j*) ;
Annamalainagar, Bh. 13 (1*m*) ;

Negapatam, Mrs. Robinson, 1928, 586, 961 ;
Sidpur (North Kanara), Sedgwick, 1919, 124 ;
Perumalmalai, Palni Hills, Foreau, 1932, 2118.

Fimbriaria Nees.

F. augusta St. (1 : 63).

Kotagiri, Rangachariar, 1916, Bh. 16 (1*e*).

F. Blumeana Nees (1 : 62).

Nilgiris, Rangachariar, 1916, Bh. 16 (4*a*) ;
Mahableshwar, Sedgwick, 1921, 125 ;
Mahableshwar, Blatter, 1917, 566 ;
North Kanara, Sedgwick, 1919, 128 ;
Perumalmalai, Palni Hills, Foreau, 1932, 2119.

F. mussurienses Kash. (1 : 64).

Panchgni, Blatter, 1927, 545, 556.

F. vulcanica (Schiffner) St. (4 : 114).

Negapatam, Mrs. Robinson, 1928, 959.

Fimbriaria mysorensis Kash. Ms.

Dicœcious, closely creeping, simple or slightly branched, up to 10 mm. long and 3 mm. broad, lobes oblong or linear oblong ; dorsal surface flat or slightly concave, margins raised up, wavy, green or purple. Stomata very small, inconspicuous, each bounded by 2 rings of 5 or 6 cells each. Dorsal layer shallow, air-chambers small, empty, ventral surface convex, hyaline or red, midrib projecting ventrally, gradually passing into the wings. Ventral scales distant, red, reaching half the wings, with appendage, appendage hyaline or red, oblong-ovate, entire, more or less acuminate. Androœcium oblong or linear-oblong, mid-dorsal, carpocephalum stalked, stalk upto 3 mm., palæceous throughout, densely so near the top, scales purple, linear. Receptacle flat, lobes 2–4, perianth hyaline 2/3 exerted. Elaters laxly monospiral upto 160 μ, usually less ; spores deep brown, broadly reticulate-lamellate, upto 60 μ, usually less.

Hab.—On ground.

Distrib.—Mysore, 1913 (Buttler), 75.

This species resembles *F. augusta* St. greatly, but can be distinguished from the latter, by the smaller pores, smaller and empty air-chambers, the stalk of the carpocephalum being palæceous throughout, and lastly by the comparatively smaller spores and elaters.

Lunularia Mich.

L. cruciata (L.) Dum. (1 : 46).
Madras, Iyengar, 1922, Bh. 18 (1*a*) ;
Ootacamund, Iyengar, 1922, Bh. 18 (1*b*).

Exormotheca Mitt.

E. tuberifera Kash. (1 : 47).
Nilgiris, Rangachariar, 1916, Bh. 19 (1*a–c*) ;
Madras, Iyengar, 1922, Bh. 19 (1*d–e*).

Dumortiera R. Bl. et Nees.

D. hirsuta R. Bl. et Nees (1 : 42).
Kotagiri, Rangachariar, Bh. 21 (2, 29) ;
Kotagiri, Sedgwick, 1916, 94, 95 ;
Madras, Iyengar, Bh. 21 (2*b–e*) ;
Negapatam, Mrs. Robinson, 1928, Bh. 21 (3*d*) ;
Palni Hills, Mrs. Robinson, 1929, 966, 968.

Marchantia L.

M. polymorpha L. (1 : 32).
Kotagiri, Rangachariar, 1916, Bh. 24 (3*d*) ;
Madras, Iyengar, 1922, Bh. 24 (3*d–g*) ;
Negapatam, Mrs. Robinson, 1928, 591 ;
Kodaikanal, Rupinat, 1932, 2120.

M. palmata Nees (1 : 34).
Nilgiris, Rangachariar, Bh. 24 (2*e*) ;
Kodaikanal, Rangachariar, Bh. 24 (2*f*) ;
Negapatam, Mrs. Robinson, 1928, 591 ;
Palni Hills, Mrs. Robinson, 1929, 964.

M. nepalensis L. et L. (1 : 36).
Madras, Iyengar, 1932, Bh. 24 (x*c*).

M. sp. only sterile and male plants. No gemmæ-cups, no carpocephala.
Negapatam, Mrs. Robinson, 1928, 587.

Marchantia indica Kashyap, Ms.

Dicœcious. In patches of overlapping individuals. Once or twice dichotomous. Thallus 2–3 cm. long and 10 mm. broad, lobes quadrate, some sterile plants upto 8 cm. long with linear lobes, flat, margin purple, crisped. Dorsal surface light green, without a dark median streak, stomata conspicuous, epidermal cells polygonal, walls and trigones thin, pores with several superimposed concentric rings of cells each of 4 or 5 cells. Inner pore

quadrate as seen from below, bounded by 4 or 5 cells with slightly convex inner walls. Ventral surface brownish, rhizoids numerous. Scales conspicuous, in 2 rows on each side of the midrib, median appendage broadly ovate, coarse with minute teeth, acute ; laminar scales close to the median ligulate. Midrib slightly convex below, gradually passing into the wings. Male receptacle not seen. Stalk of the carpocephalum 10–20 mm. long, densely palæceous at the base and top, less so throughout on the posterior side, scales linear. Receptacle asymmetrical, hemipherical, the central region well developed, half of the receptacle, rays 9-11, obcuneate with the apex often notched. Perianth hyaline. Spores and elaters immature. Margin of the gemmæ-cup not lobed, ciliate.

Hab.—On rocks and water banks.

Distrib.—Madras, Iyengar, 1922, Bh. 24 (x, x*a*) ;
Kotagiri, Sedgwick, 1915, 97 ;
Ootacamund, Curator, Botanical Gardens, 1935, 2121.

The above description agrees to a considerable extent with that of *Marchantia disjuncta* Sull. as described by Stephani in *Species Hepaticarum*, Vol. I, p. 180. But I had no opportunity of comparing the specimen described above with those of the latter, and therefore the plants described above may be identical with *M. disjuncta* Sull.

Some receptacles are androgynous, such as have already been described by Cutting.

(Cutting, E. M., " On Androgynous Receptacles in Marchantia," *Ann. Bot.*, Vol. XXIV, pp. 349–57, 1910.)

ANEURACEÆ.

Aneura Dum.

A. indica St. (1 : 112).
Palni Hills, Mrs. Robinson, 1929, 963 ;
Bangalore, Sampathkumaran, Bh. 27 (1*d*, 1*e*).

A. levierii (Schiffin.) St. (1 : 113).
Palni Hills, Mrs. Robinson, 1929, 583, 963, 969 ;
Bangalore, Sampathkumaran, Bh. 27 (3*a*) ;
North Kanara, Sedgwick, 1919, 388.

A. pinguis (L.) Dum. (2 : 109).
Palni Hills, Mrs. Robinson, 1928, 589.

A. sp.
Madras, Iyengar, 1922, Bh. 27 (x).

Metzgeria Raddi.

M. furcata (L.) Dum. (2 : 112).

Bangalore, Sampathkumaran, 1925, Bh. 28 (1) ;
Shembaganur, Foreau, 1934, 2122.

Differs from the type in having 4 cells on the lower side of the midrib, which are only 2 in the type specimens.

M. conjugata Ldb. (2 : 113).

Palni Hills, Foreau, 1934, 2123.

M. himalayensis Kash. (2 : 111).

Perumalmalai, Foreau, 1932, 2124.

BLYTTIACEÆ.

Pallavicinius Gray.

P. crispatus (Mont.) St. (4 : 316).

Kotagiri, Rangachariar, 1916, Bh. 30 (1) ;
North Kanara, Sedgwick, 1917, 387 ;
Negapatam, Mrs. Robinson, 1929, 579 ;
Palni Hills, Mrs. Robinson, 1929, 967 ;
Bangalore, Sampathkumaran, Bh. 30 (x*c*).

P. ambigus (Mitt.) St. (4 : 316).

Shembaganur, Rupinat, 2125.

CODONIACEÆ.

Calycularia Mitt.

C. crispula Mitt. (2 : 103).

Madras, Iyengar, 1922, Bh. 33 (x*a*).

Fossombronia Raddi.

F. himalayensis Kash. (1 : 99).

Bangalore, Sampathkumaran, 1923, Bh. 41 (1*g*) ;
Mahableshwar, Blatter, 1930, 1644 ;
Panchgni, Blatter, 1928, 546, 558 ;
Madras, Foreau, 1928, 162 ;
Kodaikanal, Foreau, 1934, 2126.

LOPHOZIACEÆ.

Gymnomitrium Corda.

G. sp.
Kotagiri, Sedgwick, 1915, 311.

Notoscyphus Mitt.

N. paroicus Schiffn. (4 : 37).
North Kanara, Sedgwick, 1919, 395.

Aplozia Dum.

A. cæspitica (Lindenb.) Dum. (3 : 43).
Malmane Ghat, North Kanara, Sedgwick, 1919, 390, 391 ;
Mahableshwar, Sedgwick, 1918, 394.

A. crenulata (Sm.) Dum. (3 : 141).
Kotagiri, Sedgwick, 1915, 312 ;
Kodaikanal, Foreau, 1934, 2127.

A. lanceolata (Schrad.) Dum. (3 : 153).
Kotagiri, Sedgwick, 1915, 313 ;
Kodaikanal, Foreau, 1934, 2128.

The plants are slightly smaller and a little more brownish as compared with the European specimens.

A. purpurata (Mitten) Chopra.
Kodaikanal, Foreau, 1934, 2129.

A. sphærocarpa (Hook.) Dum. (3 : 144).
Kodaikanal, Foreau, 1934, 2130.

Plagiochila Dum.

This genus has always presented a tough problem for the taxonomist. The writer, at present, is not in a position to determine all the species of this genus from India which are probably more than one hundred. Various elder colleagues have also been consulted but no help is coming forth. So it is proposed to postpone the study of Indian Plagiochilas till some suitable opportunity arises.

Lophocolea Dum.

L. heterophylla (Schrad.) Dum. (2 : 67).
Kotagiri, Sedgwick, 1916, 327–29.

L. bidentata (L.) Dum. (2 : 66).
Shembaganur, Rupinat, 2131.

L. muricata Nees (4 : 116).
Shembaganur, Rupinat, 2132.

L. sp.
Kotagiri, Sedgwick, 1915, 325.

Chiloscyphys Corda.

C. argutus Nees (2 : 62).
Palni Hills, Foreau, 1934, 2133.

C. sp.
Nilgiris, Sedgwick, 1916, 317, 318.

Saccogyna Dum.

S. subalternifolia St. (9 : 317).
Shembaganur, Rupinat, 2134.

CEPHALOZIACEÆ.

Cephalozia Dum.

C. Willisiana St. (4 : 306).
Kotagiri, Sedgwick, 1915, 322 ;
Mahableshwar, Sedgwick, 1918, 394 ;
Shembaganur, Rupinat, 1931, 2135.

C. Andreana St. (9 : 434).
Shembaganur, Rupinat, 1931, 2136.

Calypogeia Raddi.

C. arguta Nees et Mont. (3 : 322).
Kotagiri, Sedgwick, 1916, 322, 333.

C. sp.
Shembaganur, Rupinat, 1931, 2137.

Mastigobryum G. L. N.

M. intermedium L. et G. (4 : 458).
Kotagiri, Sedgwick, 1916, 323 ;
Negapatam, Mrs. Robinson, 1928, 592.

M. tridens Nees (6 : 442).
Shembaganur, Rupinat, 1931, 2138.

Lepidozia Dum.

L. tridens St. (6 : 616).
Perumalmalai, Foreau, 1932, 2139 ;
Shembaganur, Rupinat, 2140.

PTILIDIACEÆ.

Trichocolea Dum.

T. tomentella (Ehrb.) Dum. (3 : 356).
Madura, Blatter and Halburg, 1917, 564.

SCAPANIACEÆ.

Schistoila Dum.

S. aligera (Nees) St. (7 : 73).
Wallanche, Nilgiris, Gamble, 1883 ; Herb., Forest Research Institute, Dehra Dun.

RADULACEÆ.

Radula Dum.

R. complanata (L.) Dum. (2 : 44).
Kotagiri, Sedgwick, 1915, 339.

R. heterophyla St. (9 : 508).
Kodaikanal, Sedgwick, 1916, 238, 239.

R. tonkiensis G. (7 : 205).
Shembaganur, Rupinat, 2141.

R. sp.
Shembaganur, Rupinat, 1931, 2142.

MADOTHECACEÆ.

Madotheca Dum.

M. campylophylla L. et L. (2 : 29).
Kotagiri, Sedgwick, 1916, 223.

M. perrotetiana Mont. (7 : 307).
Kotagiri, Sedgwick, 1915 ;
Shembaganur, Rupinat, 1931, 2143.

M. plumosa Mitt. (2 : 30).
Kodaikanal, Foreau, 1934, 2168.

M. porella (Dicks.) Nees (3 : 416).
Kotagiri, Sedgwick, 1915, 362.

Madotheca kashyapii Chopra sp. nov.

Dicœcious. In light green patches on rocks. Stem laxly pinnate and sparsely bi-pinnate, upto 9 cm. long, pinnæ 5–15 mm. long, some longer and again pinnate. Rhizoids scarce, in tufts near the bases of amphigastria. Leaves slightly or not at all imbricate, plano-distichous ; antical base with

a minute appendage, non-decurrent, rounded with or without a tooth a little above the base, covering and often slightly crossing the stem ; postical base non-decurrent ; oblique, oblong, 1·25 mm. long and 9·75 mm. broad, margin faintly and irregularly toothed, apex broad round, apical and median cells 20–28 μ, a few basal cells only 40–50 $\mu \times$ 20–28 μ, walls thin everywhere, trigones thickened, acute in the apical and median portion, nodulose at the extreme base. Lobule small, ligulate, 0·42 mm. long and 0·22 mm. broad, base on both sides with numerous long and short teeth, margins entire often obtuse. Amphigasteria slightly broader and very similar in shape. Female branches short, lateral, with or without leaves. Involucral bracts, 1 or 2 pairs, of much the same size as the leaves, teeth a little more prominent than those of the leaves, obtuse or acute ; lobule of the same size as that of the leaf or larger otherwise similar ; bracteoles coarsely toothed throughout. Rest not seen.

Hab.—On rocks.

Distrib.—Kodaikanal, Foreau, 1934, 2144.

LEJUNEACEÆ.

Frullania Raddi.

F. squarrosa Nees (2 : 11).
Kotagiri Sedgwick, 1916, 375, 376 (Fr. Verdoorn determination) ;
Dharwar, North Kanara, Sedgwick, 1919, 389 (Fr. Verdoorn determination) ;
Shembaganur, Foreau, 1934, 2145.

F. campanulata Sde Lac. (7 : 442).
Kotagiri, Sedgwick, 1916, 380 (Fr. Verdoorn determination).

F. gracillima St. (2 : 14).
Kotagiri, Sedgwick, 1915, 534 ;
Perumalmalai, Rupinat, 1934, 2146.

F. asperula Mitt. (7 : 445).
Shembaganur, Foreau, 1934, 2147.

F. brevisulca Mitt. (7 : 350).
Coorg, Lowerie, 1896 ; Herbarium, Forest Research Institute, Dehra Dun.

F. evoluta Mitt. (7 : 451).
Shembaganur, Foreau, 1932, 104, 2148 ;
Kodaikanal, Foreau, 1935, 2149.

F. serrata G. (7 : 478).
Kodaikanal, Foreau, 1922–23, 2150 (Fr. Verdoorn determination); Shembaganur, Rupinat, 1931, 2151 (Fr. Verdoorn determination).

F. moniliata Nees (7 : 546).
Kodaikanal, Foreau, 1934, 2152.

Jubula Dum.

J. hutschinsiæ (Hook.) Dum. (3 : 444).
Kodaikanal, Foreau, 1934, 2153.

Pettolejeunea (Spr.) Schiff.

P. sp.
Shembaganur, Rupinat, 1931, 2154.

Archilejeunea (Spr.) Schiff.

A. mariana (G.) St. (7 : 729).
Kotagiri, Sedgwick, 1916, 223 (Fr. Verdoorn determination).

Ptychanthus Nees.

P. perrottetii St. (7 : 751).
Mahableshwar, Sedgwick, 1918.

P. pyriformis St. (7 : 751).
Kodaikanal, Foreau, 1934, 2155.

Mastigolejeunea Spr.

M. indica St. (7 : 776).
Tigershola, Foreau, 1934, 2156.

Ptychocoleus Trevis.

P. pulupenangensis (G.) St. (8 : 51).
Kotagiri, Sedgwick, 1916, 233–37.

Lopholejeunea Spr.

L. subfusca (Nees) St. (8 : 86).
Kodaikanal, Foreau, 1934, 2157 (Fr. Verdoorn determination); Kotagiri, Sedgwick, 1916, 233–37 (Fr. Verdoorn determination).

L. sp.
Mysore, Kashyap, 1924, 1902.

Brachiolejeunea Spr.

B. sandvicensis (G.) Evan. (8 : 136).
Kodaikanal, Foreau, 1934 *m*, 2158 (Fr. Verdoorn determination); Perumalmalai, Foreau, 1934, 2159 (Fr. Verdoorn determination).

Prinolejeunea Schiffner.

P. sp.
Mysore, Kashyap, 1924, 1902, 1904/S 3 ;
Perumalmalai, Foreau, 1932, 2161.

Eulejeunea St.

L. flava (Swartz.) Nees (3 : 427).
Mysore, Kashyap, 1924, 1904/S 6 ;
Kotagiri, Sedgwick, 1916, 225, 266 ;
Shembaganur, Rupinat, 1931, 2162.

L. cavifolia (Ehrh.) Lindb. (3 : 430).
Kotagiri, Sedgwick, 1916, 226 ;
Kodaikanal, Foreau, 1934, 2163.

L. lowriana St. (8 : 779).
Coorg, Lowerie, Herb., Forest Research Institute, Dehra Dun;
Kotagiri, Sedgwick, 1916, 224.

L. sp.
Perumalmalai, Foreau, 1934, 2164.

Microlejeunea (Spr.) Jack et Steph.

M. ulcina (Taylor) Spr. (3 : 436).
Palni Hills, Foreau, 1934, 2123.

Leptocolea Evans.

L. marginata (L. et L.) Evans (8 : 844).
Mysore, Kashyap, 1924, 1903, 1904.

L. ocellata Horikawa (10 : 86).
Mysore, Kashyap, 1924, 1902.

Physocolea Spr.

P. sp.
Shembaganur, Foreau, 1935, 2165.

ANTHOCEROTACEÆ.

Aspiromitus St.

A. mangloreus St. (8 : 967).
Bangalore, Sampathkumaran, 1923, Bh. 174 B (1, 1*a*) ;
Palni Hills, Foreau, 1932, 2166.

Anthoceros L.

A. himalayensis, Kash. (1 : 25).
Mahableshwar, Blatter, 1926, 559.

A. erectus Kash.
Travancore, Krupp. 1924, Bh. 174 (*e*).

A. lævis L. (3 : 461).
Nilgiris, Rangachariar, 1916, Bh. 174 (4, 4*a*) ;
Palneys, Mrs. Robinson, 1929, 965.

A. macrosporuous St. (8 : 1005).
Kodaikanal, Foreau, 1934, 2167.

Notothylas Sull.

N. indica Kash. (1 : 29).
Madras, Iyengar, 1922, Bh. 176 (1*a*).

BIBLIOGRAPHY.

1. Kashyap, S. R. .. *Liverworts of the Western Himalayas and the Punjab Plain* (1929), Pt. 1.
2. Kashyap, S. R., and Chopra, R. S. *Liverworts of the Western Himalayas and the Punjab Plain* (1932), Pt. 2.
3. Macvicar, S. M. .. *Students Handbook of British Hepatics*, 1926.
4. Stephani, F. .. *Species Hepaticarum* (1900), **1**.
5. ———— .. *Ibid.* (1906), **2**.
6. ———— .. *Ibid.* (1906–1909), **3**.
7. ———— .. *Ibid.* (1909–1912), **4**.
8. ———— .. *Ibid.* (1912–1917), **5**.
9. ———— .. *Ibid.* (1924), **6**.
10. Horikawa, Y .. "Studies in the Hepaticæ of Japan," *Jour. Sc. Hirshima Univ.*, Ser. B., Div. 2, 1932, **1**.

OBSERVATIONS ON THE REPRODUCTIVE SYSTEM, EGG-CASE, EMBRYOS AND BREEDING HABITS OF *CHILOSCYLLIUM GRISEUM* MULL. AND HENLE.

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Received April 16, 1938.

Introduction.

Several Elasmobranchs have been recorded from the Indian Coasts. Many of these are viviparous forms and just a few, oviparous. Our knowledge of the life-history of these fishes is confined to descriptions of embryos of some of these forms by Alcock (1890, 1892), Southwell (1910), Wood Mason and Alcock (1891, 1892), Southwell and Prashad (1919). In regard to the oviparous form *Chiloscyllium griseum*[1] the egg-case was described by Sundara Raj (1914), Southwell and Prashad (1919) and that of *C. indicum* by Smedley (1926) and Deraniyagala (1934). Embryos of *C. indicum* were described by Smedley (1926) and Deraniyagala (1934). Their descriptions are incomplete in several respects. We are not aware of any record of the embryos of *C. griseum* nor is there any definite information regarding the duration of incubation and breeding. The following is the first connected account of the life-history of an Elasmobranch from the Indian Coast.

More than 2 dozen specimens of *C. griseum* were obtained during the years 1936–38. Of these six alone were fully mature, while the rest were mostly immature with the ovaries yet undeveloped. Of the mature specimens, the first was captured on 5–2–1937, the second on 8–2–1937, the third on 11–2–1937, the fourth on 25–3–1937, the fifth on 31–1–1938 and the sixth on 15–3–1938. That obtained at the end of January last is the largest and measures 29″ long and 4·5″ broad. The remaining five are about equal and measure 26·5″ by 3·5″ approximately.[2] All the six specimens had the abdomen distended.

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[1] We are indebted to Dr. S. L. Hora of the Zoological Survey of India for sending us the necessary references relating to identification of the form.

[2] The length was taken from tip of snout to end of caudal fin and the width just in front of the pectoral fins.

Reproductive System.

For the purpose of this description the reproductive organs of the specimen obtained on 5–2–1937 has been taken. The single ovary (Pl. XXV, Fig. 1) which had a measurement of 125 mm. in length and 50 mm. in breadth and 18 mm. in thickness in the fresh condition contained 33 huge bluish green eggs and a large number of smaller light yellow ova. The other organs were almost completely hidden away from view by the huge ovary. The attachment of the epigonal organ to the ovary is very slender and the organ itself is thin and strap-shaped. There is a common median wide oviducal opening with thin-walled soft extensible lips (Pl. XXV, Fig. 2). The cranial part of the oviduct measures 62 mm. in length and 8 mm. in width. When slit open it is found to be traversed by longitudinal folds which are not single and continuous, but made up of tiny folds, each of which is cut up into leaf-like bits, free at the tips but continuous below, so that the crests of the long folds give rise to an undulating appearance (Text-Figs. 1 and 2).

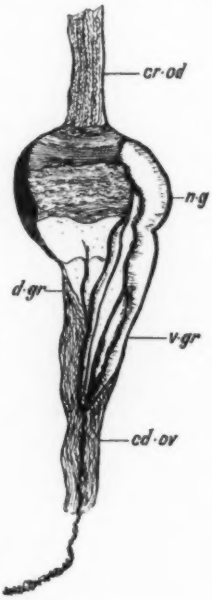

Fig. 1.

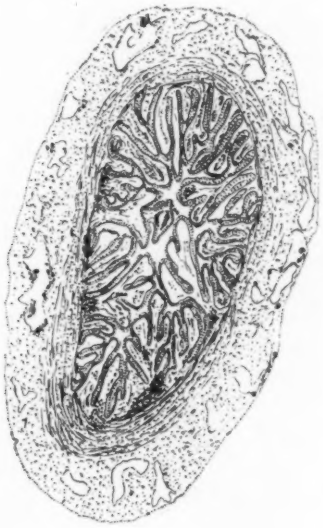

Fig. 2.

Both the shell-glands are equally developed and each measures 50 mm. in length and 37 mm. in breadth at the swollen portion. When cut open, the inner surface of the gland shows three zones (Text-Fig. 3). The first zone is composed of alternating shallow grooves and low ridges, the second

or the middle (the broadest) consists of very delicate lamellæ with slightly wavy tops, the third is formed of a dense glandular zone with a comparatively smooth inner surface. On the ventral side there is a very prominent groove starting from the middle of the gland and extending down an inch and a half below the swollen portion and continuous with the lumen of the caudal part of the oviduct below. A shallow groove occurs also on the dorsal surface but it is not so conspicuous as the ventral one. Into the grooves open densely packed very fine filamentous tubules running horizontally towards them. Both the glands were rather flaccid in the fresh condition having apparently just then disgorged the egg-case into the uteri.

The caudal portion of the oviduct measures 45 mm. in length and 33 mm. in width. Internally it is lined with longitudinal ridges which are smooth and entire but wavy. Between the caudal oviduct and the entrance into the uterus is a powerful sphincter (Text-Fig. 4). Here the longitudinal

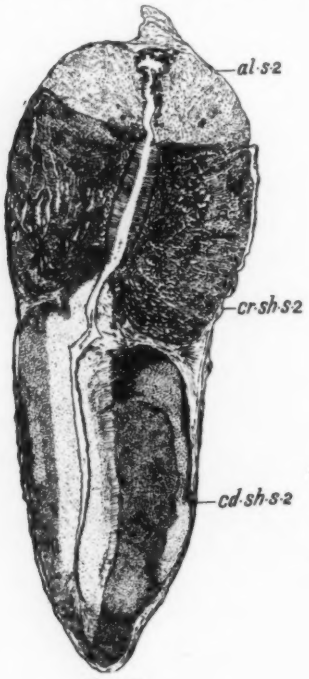

Fig. 3.

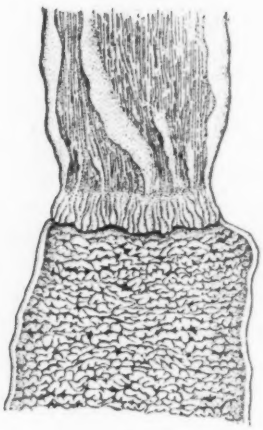

Fig. 4.

ridges crowd and become closely pressed against each other. The uterus measures 75 mm. in length and 40 mm. in width. On opening the uterus which was tensely stretched it was found to contain one boat-shaped egg-

case, which was smooth, hard and chitinous. Between the uterus and the egg-case there was a little uterine fluid. The inner surface of the uterus is traversed by a large number of transverse folds. The above description would apply to all the remaining five specimens except that in two of them each uterus contained two egg-cases instead of one and in a third there were three egg-cases on each side. In the last specimen the capsules of the first pair were symmetrically placed opposite each other whereas one of the fellows of the third pair had slipped partly down into the cloaca.

Some of the egg-cases were removed and suspended in sea-water which was kept aerated and renewed at frequent intervals. The capsules had the benefit of direct sunlight entering the sea-water room in the mornings. The temperature of the water was near 25° C. Developing eggs were taken out at definite intervals and examined. Three of the eggs did not develop properly. This can only be explained by the probable rough handling of the fish before they were brought to the laboratory and the consequent 'jar' that the eggs would have received.

Egg-Case.

The 20 capsules found in the six specimens are of about the same size. They range from 75–80 mm. in length and 35–40 mm. in width, with an average thickness of 16 mm. They are of a yellowish brown colour, with the thickened edges of a deeper brown.

The capsule is more or less quadrangular but slightly asymmetrical (Text-Fig. 5). One of the two long sides is more curved and therefore

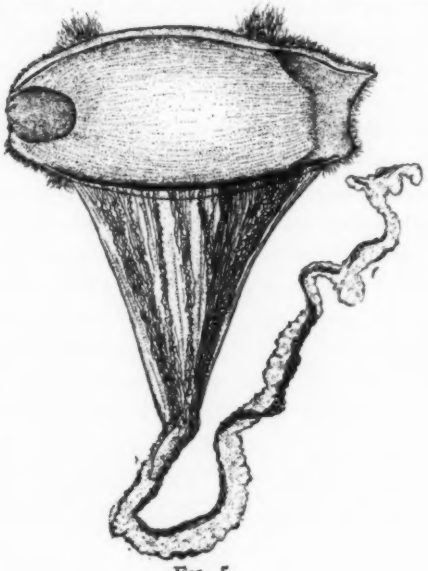

Fig. 5.

longer and this side has two short tufts of filaments. Along the opposite long edge is the characteristic broad band composed of silky fibres which gradually twist into a long cord, measuring 6·8 inches intended for attachment of the capsule to sea-weeds or other similar objects. The two long edges come closer together at the posterior end than at the anterior. The more curved side is the dorsal side considering its orientation inside the uterus. But actually, however, the capsules turn over with the uterus and present the more convex side directed away from the mid-line of the body-cavity. There is an oval slightly transparent area at the posterior end which is presented first during oviposition ; into this the cavity of the capsule does not extend. At the anterior end also the two surfaces are pressed against each other, an intervening cavity being absent. When the egg-cases were gently removed from the uteri, the twisted cord formed by the tapering broad band was found lying in the lumen of the caudal part of the oviduct with the terminal part of the cord lodged in the posterior portion of the ventral nidamental gland groove. The whole twisted cord lay freely in the lumen so that when the capsule was removed it came off easily. It seems highly probable that this portion (cord) is formed last. Deraniyagala says that only half the long edge was covered with elongate anchoring filaments in his egg-cases of *C. indicum*. But the specimens in our possession show that practically the entire edge is covered with these silky filaments though it is not so prominent or concentrated at the two ends as towards the middle. Besides the two short tufts and the large band mentioned, there are slender silky threads fringing the edges as observed by Sundara Raj though Deraniyagala does not mention this for *C. indicum*. Sundara Raj did not find any prolongation into tendrils at the four corners. Nor do we find any in the egg-cases with us. But Southwell and Prashad (1919) describe a pair of poorly developed filaments (tendrils) at one end and a shorter pair at the other. They also mention and figure two short tufts of filaments at two places along the longer side. It seems to us that the filaments from the corners may or may not be formed and they constitute a variable character. Clark's (1922) researches on the Rays have shown that the egg-cases of the same fish may show slight variation in size and in other minor details.

In the case of one of the specimens with two egg-cases in each uterus, the twisted silky filaments of the anteriorly situated egg-cases had the tips lodged freely in the gland-grooves, while the filaments of the posterior egg-cases were curled up and lay freely in the uteri between the two egg-cases. The uteri of the specimen with the three egg-cases in each uterus were absolutely packed from end to end. This shows that the secretion of the egg-case together with the accessory appendages is very rapid, and probably

3 pairs form the maximum number that could be accommodated in the uteri at a time. There is no doubt that the eggs are fertilized in the upper parts of the oviduct. Dean (1895) and Lo Bianco have clearly stated this as their opinion. As gravid females confined in aquaria in which no males were present, have laid several pairs of eggs it can only be as the result of the eggs getting fertilized by sperms retained in the reproductive system of the female for a long time in a living condition.

The egg-case has 4 slits, one situated at each of the four corners. In a side view of the egg-case only two are seen as the other two are placed along the opposite long edge but are visible on the other side only. They are plugged with a gelatinous substance and when this is removed carefully the slits are found to lead into the cavity of the capsule. Sundara Raj (1914), Southwell and Prashad (1919) do not mention the slits in their description of the egg-case. Deraniyagala (1934) speaks of an " opening at the edge of one corner " permitting the water to enter. He thought that the opening is used for the intake of water while Beard (1890) believed that a current is non-existent, and that the slits are intended to counteract pressure. We believe that these slits are for the entrance of water, for, when after a time the albumen is exhausted probably by the trophonematic activity of the branchial filaments, the plug gets dissolved and the water enters freely. This is helped by the movements of the embryo inside, allowing a free interchange of water between the outside and inside. Clark (1922) also believes that the slits are for the interchange of respiratory water. When the capsules are lifted out, the water inside rapidly drains off and the capsule floats on the surface. Care must be taken to immerse the capsule and to fill its inside once more with water by gently pressing it between the fingers and releasing the pressure once or twice. Otherwise the embryo will perish.

Development during the First Week.

The blastoderm of an egg taken from a capsule about to be laid is yellowish in colour and is in the form of a circular halo and measures 3–4 mm. in diameter. After three days of development the blastoderm has the appearance shown in Text-Fig. 6. It is circular in outline and has a diameter

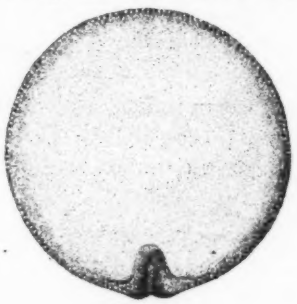

Fig. 6.

of 0·5 mm. One side of the edge of the blastoderm is thickened and here the medullary groove has commenced to form and has extended to one-fifth of the distance across the blastoderm. During the fourth and fifth days, growth is rapid and the medullary folds grow rapidly forwards. The medullary groove gets deepened behind, but remains wide and shallow in front. The sides of the folds in the front region get so much flattened that they give rise to a plate-like structure, the cephalic plate of some authors. The head end and the sides of the developing embryo get raised and folded off from the blastoderm. Blood-islands have formed during the third and fourth days, giving rise to a network-like peripheral ring. Five pairs of vertebral somites could be counted on the completion of the fourth day of development. During the next two days quick transformation of the embryo takes place. The meduallary groove closes and the tail end gradually projects beyond the hind edge of the blastoderm. Mesoblastic thickenings on either side of the tail now manifest themselves clearly.

Embryo One Week Old.

The blastodermic area measures 25 mm. in diameter, the rim of the area being very thick. The embryo is clearly visible and has lifted itself out of the yolk and measures 5 mm., is perfectly white in colour, and shows active movements (Pl. XXV, Fig. 3). The separation of the embryo has so far progressed that one can already speak of a definite broad but short yolk-stalk. The embryo now corresponds to stage H of Balfour (1878). The brain clearly consists of the usual three divisions—the fore, middle and the hind-brain. The tail is long and slightly broadened. The primary optic vesicles have become clear. The auditory vesicles are just visible as translucent circles. The heart has developed. The tail is slightly dilated and the usual cranial flexure has commenced. As many as 26–28 vertebral somites could be counted at the commencement of the second week of development in healthy embryos and there is an unsegmented region on either side of the tail.

Embryo Two Weeks Old.

This is very nearly equivalent to stage K of Balfour (Text-Fig. 7 and Pl. XXV, Fig. 4). The embryo now measures 10 mm. The blastodermic area

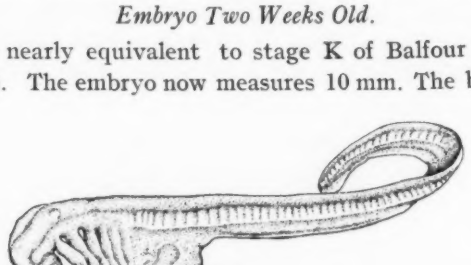

Fig. 7.

has extended almost half round the yolk-mass. The yolk-stalk has become narrow but slightly longer. The cranial flexure has become very pronounced. The position of the anus is now clear. The mid-brain is conspicuous and now forms the front end. The optic vesicles have closed but the lens could not be made out. The mouth has commenced to form as a median slit. The alimentary canal has extended forwards and backwards. Four pairs of visceral slits could now be made out with faint indications of a fifth pair. The branchial filaments have begun to appear as faint projections. The auditory vesicles are now clear. Fin differentiation has progressed rapidly. There is a dorsal median and a ventral median fold. In addition there are two delicate lateral thickenings but the boundaries of the paired fins cannot be made out.

Embryo Three Weeks Old.

Length	40 mm.
Yolk-sac	22 „
Tip of head to hind end of pelvic fins	14 „
Yolk-stalk	12 „

The stage corresponds to stage O of Balfour (Pl. XXVI, Figs. 5 and 6). The albumen has been completely absorbed. The vitelline arteries and veins are fully developed. The tail has lengthened out considerably. Pectoral fins, pelvic fins and the two dorsal and caudal have assumed their respective positions. The ventral median fin-fold is almost continuous from behind the pelvics to the tip of the caudal fin. Two minute indentations already mark the end of the anal and the commencement of the caudal. All the six pairs of visceral clefts are fully formed. The spiracles are situated midway in the interval between the eyes and the gill-slits.

The eye vesicles are fully formed and the lens is clear and pigmented. The nasal depressions are distinct but not confluent with the now squarish mouth. All the gill-slits are now clear and projecting from the outer tips of the internal gill-lamellæ are a number of vascular branchial filaments provided with vascular loops. The filaments of the spiracular clefts are only half the length of the filaments from the other gill-slits. The filaments from the posterior gill-slits are very much shorter than those shown for *C. indicum* by Deraniyagala and reach only the hind edges of the pectoral fins. These filaments are not only respiratory but also serve probably for the absorption of the albumen. In this respect the respiratory function may be said to commence after the albumen has been absorbed. The mouth-cavity has widened and has become deep. The animal is very active. The gelatinous plugs of the slits on the capsules have not yet been dissolved away.

Embryo One Month Old.

Length	45 mm.
Tip of head to hind edge of pelvic fins	16 ,,
Yolk-sac	20 ,,
Yolk-cord	5 ,,

This stage is very much like the previous stage. The embryo has grown longer (Pl. XXVI, Fig. 7). There has been a rather sudden shortening of the yolk-cord. The branchial filaments have become denser. The buccal opening has become transverse. Nasal depressions are conspicuous in front of the mouth. The nasal tentacles have sprouted out and the mouth has become connected with the nasal depressions. The interval between spiracles and the eyes is very much less than in the previous stage. There is a ring of pigment round the lens. The surface of the body is not pigmented. The pectoral, the pelvic, the first dorsal and the second dorsal are distinct. The caudal fin extends along the median ventral line some distance beyond the commencement of the second dorsal and now shows two dents, the first of which will later on separate off the anal from the caudal. On either side of the caudal there are two rows of serrated denticles 11 in the upper row and 7 in the lower (Text-Figs. 8 and 9). Deraniyagala mentions 16 and 13 denticles from an embryo of 53 mm. of *C. indicum*. The surface of the yolk-sac is highly vascular. With the disappearance of the albumen rapid absorption of the yolk has commenced.

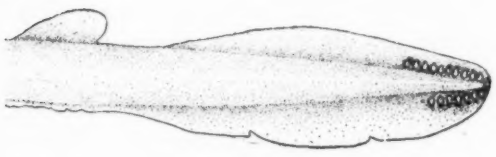

FIG. 8.

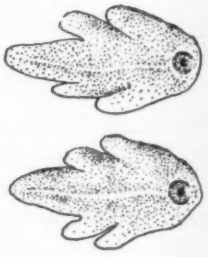

FIG. 9.

Embryo Two Months Old.

On the completion of the second month of development one of the capsules was taken and long slit-like windows were cut on one side to observe the movements of the enclosed embryo.

Length	100 mm.
Width of embryo in front of pectorals ..	18 ,,
Tip of head to hind edge of pelvic fins ..	40 ,,
Diameter of yolk-sac	18 ,,
Length of yolk-cord	15 ,,

The embryo was found coiled round the yolk-sac with its head pointing towards the posterior end of the capsule (Text-Fig. 10). All the fins have assumed the adult character and the characteristic colouration which is described in connection with the next stage has become fully established. The part of the median ventral fin-fold (the anal membrane) in front of the anal has become absorbed. The nasal tentacles (barbels) are prominent and now reach the margin of mouth. The embryo is a male and the claspers are well formed. Teeth have broken through. All traces of the branchial filaments have disappeared. Vigorous respiratory movements of the gill region were noticeable causing rhythmic lateral movements of the embryo as a whole. In the position in which it was found the back of the embryo was directed towards the right side of the capsule. Now and then the embryo revolves round, in a circle. In the limited space no other movements seemed possible.

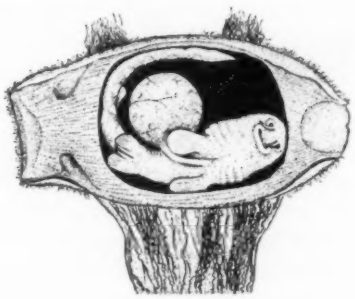

FIG. 10.

Embryo 70 Days Old.

Length of space inside capsule	45 mm.
Breadth of space inside capsule	20 ,,
Length of the embryo	110 ,,
Diameter of yolk-sac	6 ,,
Breadth at the broadest part	16 ,,
Yolk-cord	5 ,,
Tip of head to hind edge of pelvic fins ..	45 ,,

The embryos are found curled up and are incapable of any movement in the limited space available ; when one was taken out and placed in a jar of sea-water it swam in circles with energetic movements of the tail. After two days the yolk-sac had become further reduced after which the embryo was fixed. Colouration has become fully established (Text-Fig. 11 and Pl. XXVI, Figs. 8 and 9).

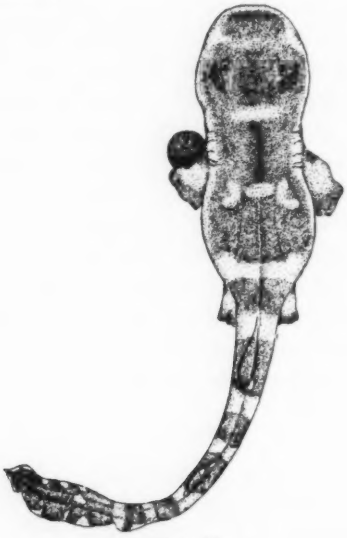

Fig. 11.

Looked at from the dorsal side, there are twelve white bands. The first is immediately in front of the eye, the second passes across the broadest part of the head of the animal, *i.e.*, just behind the spiracle, the third and fourth behind the level of the pectoral and in front of the ventral fins respectively. The fifth crosses the body just in front of the first dorsal fin. The next one divides the interval between the first and second dorsal into two. The seventh band occupies a position in respect of the second dorsal which the fifth does to the first dorsal. The remaining five bands divide the part of the body behind the tail into six equal spaces. The tip of the tail is white.

All the twelve bands are peculiar in that their outer ends are swollen into large white spots decreasing in size from before backwards.[3]

The number of caudal denticles in the specimen has increased (Text-Fig. 12). There are 19 in the upper and 13 in the lower row. Deraniyagala

[3] Young specimens slightly larger in size were caught on 20–4–1937 and in these the white bands showed signs of fading.

thinks that these denticles have the function of fixing the embryo to some part of the inside of the egg-case to prevent too violent movements and a premature exit from the egg-case.

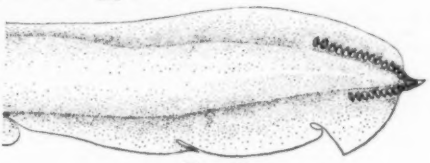

FIG. 12.

There does not appear to be any justification for this belief. Active movements of the embryo could easily be seen through the egg-case and the authors believe that it is these movements which bring about renewal of water in the egg-case especially in the earlier stages. Clark attributes a similar function to the elongated caudal fin of *Raja nævus*. An egg-case removed from the fish and allowed to develop on 31st January 1938, hatched out on 21st April 1938, exactly after eighty days' incubation. The embryo was seen wriggling out, forcing its way through the anterior end of the egg-case. The yolk-sac was found to have been completely absorbed, leaving just a scar at its point of attachment on the ventral side of the body.

Clark (1926) from a consideration of the measurements of the total length of embryos and the distance from tip of snout to origin of the first dorsal, came to the conclusion that there is a differential growth of the parts pre-dorsal and post-dorsal. After a certain length has been reached the length of the post-dorsal remains practically stationary while the pre-dorsal length shows progressive growth.

The following table gives the measurements of *Chiloscyllium griseum* of different ages.

Specimen	Age	Total length	To end of pelvic fin	Rest of body
		mm.	mm.	mm.
1	21 days	40	14	26
2	30 ,,	45	16	29
3	60 ,,	100	40	60
4	70 ,,	108	45	63
5	80 ,,	130	55	75
6	Adult of unknown age	620	290	330

An analysis of the figures given in the table above indicates the rates of growth of the anterior part (from the snout to hind edge of pelvic fins) and of the posterior part (from the pelvic fins to the tip of the tail) of the growing embryo are different. For example, the head and trunk region has elongated from 14 mm. to 45 mm. during an increase of age from 21 to 70 days, while the tail region has recorded a growth from 26 mm. to 63 mm. Thus it is fairly clear that the anterior end develops at a slightly higher rate than the posterior. This is as it should be for, the length of the tail is proportionately greater in the earlier stages than in the adult.

Breeding Period and Duration of Development.

In deciding this question the following facts may be taken into consideration :—

Sundara Raj collected his egg-case of *C. griseum* from the Madras Aquarium on the 27th January 1913. Southwell and Prashad obtained their two egg-cases of the same species from the Gangetic delta in March 1918. Deraniyagala obtained his egg-cases of *C. indicum* in March 1933. Smedley's record of his egg-cases of *C. indicum* unfortunately does not give the date of collection. The egg-cases obtained by us were from females captured during January–March period. Very young *C. griseum* measuring 130 mm. have also been obtained in the month of March from the fisherman's catches. Judging from these facts and bearing in mind that the incubation period is about two months and a half, one might be led to conclude that the period of spawning is restricted to the months of January, February and March along the Madras Coast. But the fact that it was possible to obtain embryos measuring 100–125 mm. now and again throughout the year seems to point to a different conclusion. This would mean that early in the year the gravid females seek sheltered situations near the Coast for purposes of egg-laying and that as the year advances they seek deeper waters with the result that they escape the fishermen's net. No other explanation seems to be possible for the capture of very young specimens in small numbers during the year. Similar observations of a fairly prolonged breeding period have been recorded by Beard for the Skate *R. batis* and the Ray, *R. nævus* in the North Sea ; and for *R. punctata* in the Naples Bay by Lo Bianco. It is highly probable that the capsules are deposited in favourite spawning grounds.

Madras gets a fair proportion of its supply of sharks by trains during certain months of the year from Malabar. An examination of a small heap of *C. griseum* in one of the fish markets of Madras early in December 1937 revealed two specimens with egg-cases. One was 21·5" long and was in the gravid condition, with an egg-case in each uterus. The nidamental glands

were in a high state of activity and the ova were of the maximum size. The second specimen measuring 22·5″ was also mature, with the ovary containing large-sized bluish green ova, but these were fewer than in the first specimen. The nidamental glands were fully active, but no egg-case was found in the uteri which were flaccid and represented a condition probably just after the release of the egg-capsules into the sea. The fact that fewer ova occurred in the ovary of this fish is itself sufficient to prove that some of them had already descended into the uteri surrounded with the capsular covering and had been liberated into the sea by the fish.

Comparing the sizes of the mature forms of Madras and Malabar it seems that the Malabar specimens attain maturity when they are relatively smaller than the Madras forms. It would mean either that the maximum size that the fish is capable of attaining in the Malabar Coast is less or that if the maximum size is taken as about equal, then the reproductive maturity sets in earlier on the Malabar Coast than on the East Coast. In the absence of more detailed data on this question nothing definite could be stated. The egg-capsules of the Malabar form are also smaller than those of Madras specimens. Those of the former measure 60 mm. in length and 25 mm. in width; while the latter 70–80 mm. in length and 40 mm. in width. The difference in size is in accordance with the statement of Clark (1912) that considerable variation is apparent in the Mediterranean capsules as compared with the Plymouth ones of the same species. He makes a suggestion that the mature fish of the same species are smaller in size in the Mediterranean and Lo Bianco's (1908–09) observations are in conformity with this. Variation in individuals of the same species has led several workers like Jordan and Evermann (1896) and Garman (1913) to adopt a classification according to distribution.

Regarding the period of incubation (*i.e.*, the period of development inside the egg-case) it is now clear, from the facts available, that for this Indian form it is not at all so long as in the case of the European Elasmobranchs. Clark gives, for instance, for *Raia marginata* 14¾ months. He also records other cases with the incubation ranging from 4½ to 8 months. Kerr mentions 20 months for *Raja batis* and says that for this form the effect of temperature is so great that the December eggs of this form are overtaken in their development by the April eggs. This may be so for several of the European forms, but for the species under consideration this period cannot be much more than 2½ months. Sundara Raj's statement that "the period of gestation is probably very long in dog-fish" is clearly an error as he seems to use the term "gestation" to mean period of development inside the parent, which we know to be very short in oviparous forms. It would

otherwise be impossible for oviparous forms to produce and liberate as many as 25 capsules in a short time. In our specimens the blastoderm had just commenced to divide and there were other eggs coming down.

Smedley suggests a "lengthy period" of incubation judging from the presence of hydroid organisms. Work done in this Laboratory has clearly shown that in the tropics hydroids grow very rapidly. For instance, *Laomedea spinulosa* becomes mature sexually in nine days and further these are constantly being browsed down by small animals. Consequently, we cannot judge the period of incubation from the size and nature of hydroid growth on the egg-capsule.

It seems to us that the comparatively short period of development is in accordance with the general shortening of development that seems to exist in a number of tropical forms as has been shown in this Laboratory by work on *several organisms* (Paul, 1937), *Salmacis* (Aiyar, 1935) and *Acentrogobius* (Aiyar, 1935).

Egg-Liberation.

In all the six gravid specimens examined by us the ovary was in a state of full development. There were in each case more than 30 full-sized eggs, each as big as those enclosed in the egg-capsules. Southwell and Prashad mention an egg-case in each uterus. It is only when the cloaca is almost reached that one of the egg-cases takes a slight precedence over the other and is presented first. Further, the observation of those who have watched the behaviour of some of the Elasmobranchs in aquaria goes to show that the eggs are deposited in pairs, the two capsules of a pair coming out one after the other in quick succession. Clark mentions that in the case of *Raia brachyura* as many as 25 were laid during the course of 20 days between the 12th April and 31st of May of 1922. He says that one capsule would be followed immediately by another. Then there would be a pause for a day which would be followed by another pair. This appearance of eggs spawned in pairs, he thought, was in keeping with the maturation of a single ovum from each ovary, there being two in *Raia brachyura*. The fact that in one of our specimens there were three pairs of capsules (3 in each uterus) closely packed one behind the other and that the ovary still had several fully-developed eggs can only mean that the eggs are liberated at very short intervals.

Our observations are in accordance with the facts recorded by Fr. Kopsch who studied the egg-laying of *Scyllium canicula* in the aquarium at Rovigno. Two eggs were laid almost at the same time. He further states that between the temperature 11° and 16° C. "The stage reached is a function

of time and temperature ; thus if a stage x be reached in six days at 10° C., the same will be reached in four days at 15° C."

In *C. griseum* there is only a single ovary and the evidence available goes to show that the egg liberation is very similar. Sundara Raj observed rapid laying of eggs in *C. griseum* in the Madras Aquarium tanks though unfortunately no details are given.

Smedley mentions a cluster of three eggs of *C. indicum* attached by continuous strands and he suggests the possibility of the eggs being laid in threes. This does not seem probable. The eggs have been seen by us in the uteri of the Madras form placed opposite to each other and since in the specimens which contained more than a pair, the capsules were one behind the other the probability is that they are laid in pairs, one egg-case being followed rapidly by another. The presence of a single ovary only need not offer any difficulty. The ovary matures two eggs in rapid succession which one after the other find their way into the oviduct. Widakowich (1908) has pointed out how the congestion of blood in the posterior cardinals at the time of egg liberation helps in the process of rapidly pushing the egg into the median oviducal opening. Hobson (1930) points out that in *Raia radiata* which has two ovaries, the pairs of eggs may be formed alternately in each ovary. Dean (1906) believes that a very similar occurrence takes place in Chimæroids and suggests an alternate liberation of eggs from the ovary. He thinks that the fluidity of the eggs at this stage unquestionably aids easy entry into and smooth passage through the narrow oviduct. The condition of *C. griseum* is very similar and may be taken as a step in advance developed in correlation with the complete suppression of one of the ovaries. The eggs are fertilized as they come down the upper reaches of the oviducts ; they get a coating of albumen and shell substance in the nidamental glands and finally pass rapidly down the oviducts to be extruded from the cloaca.

Summary.

The complete life-history of *Chiloscyllium griseum* from Madras is described in detail.

A description of the reproductive system and the egg-case is given. There is a single ovary and a common oviducal opening. The nidamental glands are well developed.

An account of the different stages of development is given.

The breeding period commences probably in January and extends over several months.

Eggs are probably liberated in pairs, the two eggs of every pair escaping in quick succession.

The time taken for development of the egg into a full-grown embryo before it is liberated is very short being 2½ to 3 months unlike the very much longer periods taken in colder regions by allied forms.

BIBLIOGRAPHY.

Aiyar, R. G. .. "Observations on the development of *Acentrogobius neilli* (*Gobius neilli* Day)," *Zool. Anz.*, 1935, **Bd. 3.**

———— .. "Early development and Metamorphosis of the Tropical Echinoid *Salmacis bicolor* Agassiz," *Proc. Ind. Acad. Sci.*, 1937.

Alcock, A. .. "Observations on the Gestation of some Sharks and Rays," *J. Asiatic Soc. Bengal*, 1890, **59.**

———— .. "On Utero-gestation in *Trygon bleekeri*," *Ann. Mag. Nat. Hist. Lond.*, 1892, **9.**

———— .. "Some observations on the Embryonic History of *Pteroplatea micrura*," *ibid.*, 1892, **10.**

Balfour, F. M. .. *A Monograph on the Development of Elasmobranch Fishes*, 1878.

Beard, J. .. "On the development of the common Skate (*Raia batis*)," *8th Report Scot. Fish. Board*, 1889–90.

Bianco, Salv. Lo. .. "Notizie Biologische, miguardante specialmente il periodo di matura sessuale degli animali del Golfo di Napoli," *Mith. Zool. Stat. zu. Neapel*, 1908–09, **19.**

Clark, R. S. .. "Rays and Skates, I. Egg Capsules and Young," *J. Mar. Biol. Assn.*, 1922, **12.**

———— .. "Rays and Skates, II. Description of Embryos," *ibid.*, 1926, **12.**

Dean, B. .. "Fishes—Living and Fossil," *Columbia Univ. Biol. Ser.*, **3**, 1895.

———— .. "Chimæroid Fishes and their Development," *Carnegie Inst. Pubn.*, 1906, No. 32.

Deraniyagala, P. E. P. .. "The Embryo of the Dog-fish *Chiloscyllium indicum*," *Spol. Zeyl.*, 1934, **18.**

Ford, E. .. "Life-Histories of Dog-fishes," *J. Mar. Biol. Assn.*, 1922, **12.**

Hobson, A. D. .. "A Note on the Formation of the Egg Case of the Skate," *ibid.*, 1930, **16.**

Jordan, D. S., and Evermann, B. W. "The Fishes of North and Middle America," *Bull. U.S. Nat. Mus.*, 1896, No. **47.**

Kerr, J. G. .. *Text-Book of Embryology, II. Vertebrata*, London, 1919.

Kopsch, Fr. .. "The egg-laying of *Scyllium canicula*," *Biol. Central.*, 1897, **17.**

Paul, M. D. .. "Sexual Maturity of some Sedentary Organisms in the Madras Harbour," *Curr. Sci.*, 1937, **5.**

Scammon, R. E. "Normentafeln zur Entwicklungsgesichte der Wirbeltiere," *Jena.*, 1911. (Quoted by various authors.)

Sedgwick, A. .. "Note on Elasmobranch Development," *Quart. Jour. Micr. Sci.*, 1892, **38.**

Smedley, N. .. "On the development of the Dog-fish *Chiloscyllium indicum* Gmel.," *J. Mal. Br. of As. Soc.*, 1926, **4.**

FIG. 1.

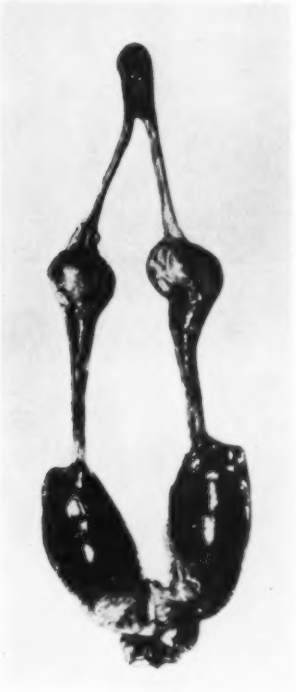

FIG. 2.

FIG. 3.

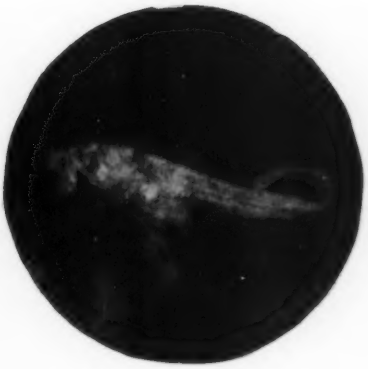

FIG. 4.

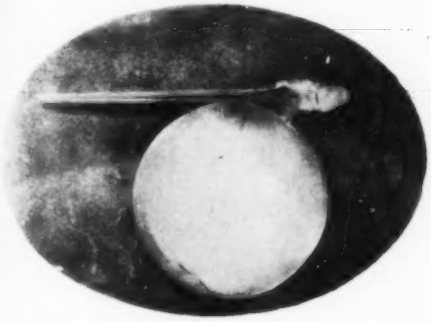

FIG. 5.

FIG. 6.

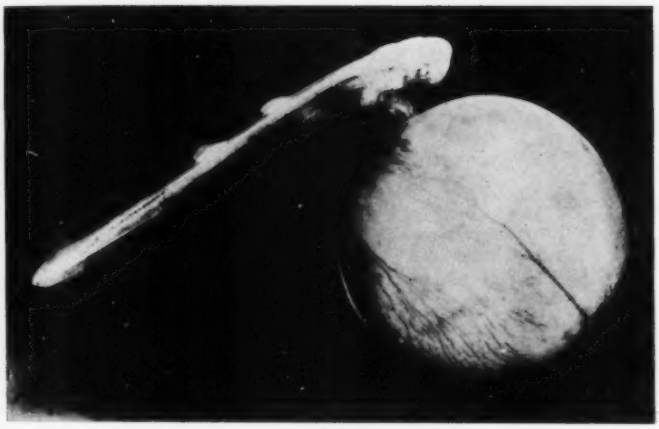

FIG. 7.

FIG. 8.

FIG. 9.

FIG. 10

Southwell, T. .. "A Descriptive Note on the capture of a large Saw-fish (*Pristis cuspidatus*) containing intra-uterine embryos," *Spol. Zeyl.*, 1910, **6**.

Southwell, T., and Prashad, B. "Studies on Indian Fishes," *Rec. Ind. Mus.*, 1919.

Sundara Raj, B. .. "A Note on the Breeding Habits of *Chiloscyllium griseum*," *ibid.*, 1914, **10**.

Widakowich, V. .. "Wie gelangt das eider plagiostomen in den Eileiter. Ein Beitrag zur kenntnis des Venensystems von *Scyllium canicula*," *Zeit. wiss. Zool.*, 1908, **Bd. 91**.

Wood Mason, J. .. "On the Uterine villiform papillæ in *Pteroplatea micrura* and their relation to the embryo," *Proc. Roy. Soc. Lond.*, 1891, **49**.

———— .. "Further observations on the gestation of Indian Rays," *ibid.*, 1892, **50**.

EXPLANATION OF TEXT-FIGURES.

TEXT-FIG. 1.—The nidamental gland cut open to show the general appearance of the inside of the gland. *d.gr.* dorsal groove; *v.gr.* ventral groove; *cr.ov.* cranial oviduct; *cd.ov.* caudal oviduct.

TEXT-FIG. 2.—Diagram of transverse section of cranial part of oviduct showing the projecting folds.

TEXT-FIG. 3.—Diagram of longitudinal section of nidamental gland showing three definite gland zones. *al.s.z.* albumen secreting zone; *cr.sh.s.z.* cranial shell secreting zone; *cd.sh.s.z.* caudal shell secreting zone.

TEXT-FIG. 4.—Diagram of inside view of caudal part of oviduct and the commencement of the uterus with the sphincter in between.

TEXT-FIG. 5.—Egg-capsule as seen from the right side.

TEXT-FIG. 6.—Blastoderm. Three days old.

TEXT-FIG. 7.—Embryo. Two weeks old.

TEXT-FIG. 8.—Caudal fin of thirty days old embryo.

TEXT-FIG. 9.—Two denticles enlarged.

TEXT-FIG. 10.—Embryo sixty days old exposed from the left side of capsule.

TEXT-FIG. 11.—Embryo seventy days old.

TEXT-FIG. 12.—Caudal fin of embryo seventy days old.

EXPLANATION OF PHOTOGRAPHS.

PLATE XXV.

FIG. 1.—A gravid female with the abdominal cavity cut open. Note huge ovary and an egg case lying to one side.

FIG. 2.—Reproductive system. Showing median oviducal opening, enlarged nidamental glands and uteri distended with egg-capsules.

FIG. 3.—Embryo one week old.

FIG. 4.—Embryo two weeks old.

PLATE XXVI.

FIG. 5.—Embryo three weeks old. Ventral view.

FIG. 6.—Embryo three weeks old. Side view.

FIG. 7.—Embryo one month old.

FIG. 8.—Embryo seventy days old. Ventral view.

FIG. 9.—Embryo seventy days old. Dorsal view.

FIG. 10.—Embryo normally hatched out. Eight days old.

ON *MYZOSTOMA GOPALAI* SPECIES NOVA FROM THE MADRAS HARBOUR.

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(Communicated by Professor R. Gopala Aiyar.)

Very recently I had an opportunity to collect large numbers of *Myzostomes* from a common Crinoid *Tropiometra encrinus* Clark (1921, 1932), from the Madras Harbour. This elongated *Myzostomid* appears to be distantly related to *M. rotundum* Graff, *M. abundans* Graff, *M. elegans* Graff (1883, 1884), *M. evermanni* McClendon (1907) and *M. polycyclus* Atkins (1927), but is very distinct from all the above to justify in my opinion the creation of a new species, *Myzostoma gopalai* to receive it.

This form commonly occurs attached to the ventral surface of the arms of the Crinoid. In freshly collected *Tropiometra* they have never been observed on the disc or near the mouth, but if the *Myzostomes* are disturbed they have a tendency to hide themselves in the spaces between the arms. The number of *Myzostomes* found on a single Crinoid varies from 1–6, however, several Crinoids were found without these ectoparasites.

The body of the animal is of almost uniform thickness, but gradually thins out towards the margins. In the attached condition the dorsal surface is convex and the ventral concave. The pharynx in the majority of the specimens is extended and contractions of this structure could be observed with the naked eye. When the *Myzostomes* are picked out and put in a dish of sea-water they always lie on their dorsal surface with the sides of the body directed upwards. If two or more individuals lie close together they have a tendency to stick by means of their suckers and all of them rolling together to form a ball-like mass. The large specimens carry young *Myzostomes* of various sizes, but more than one young has not been observed on any of the specimens.

The colour of the animal is highly variable. It has a yellowish-orange ground colour on which is superimposed a brown one. The yellowish orange occurs as irregular diamond-shaped areas in the middle line, with strands to the margins, in between which are (Plate XXVII, Fig. 1) the five brownish-orange bands. The first, fourth and last of these of either side are united

in the median line while the second and third are separated by diamond-shaped areas in the middle line. This is the typical colouration and is of a protective nature since the Crinoid arm has alternating bands of almost similar colours. But specimens which are yellowish orange or completely brownish also occur. Moreover the width and disposition of the bands show great variation. The ventral surface is yellowish.

As most workers have up till now examined only preserved material, an attempt was made to narcotize the animal with a view to determine the best method of preserving all the details. Magnesium chloride and menthol do not induce the *Myzostomes* to expand, and later preservation of animals so treated, in alcohol or formalin does not show the cirri properly. The body in such cases becomes rolled up. Narcotization under a coverslip with varying grades of alcohol is fortuitous and it appears to me that the best method is to kill the animal with Bouin or corrosive acetic while kept under pressure between two slides. The margin and the cirri are the most difficult to preserve with clarity. Among various fixatives I find corrosive acetic the best. Specimens were mounted between two slides and were irrigated with corrosive acetic. The first touch of the fixative leads to violent contraction, but if the slides are kept together by pressure a tolerably decent preservation is obtained. After ten minutes the animal is slowly removed from the slide with a brush and kept in a small dish of the fixative for another twenty minutes. This treatment renders the animal whitish making it possible to photograph it on a black background and also to study accurately the disposition and structure of the parapodia, suckers, etc., under reflected light. In the living animal and in one mounted after clearing there is a transparent marginal zone free of alimentary canal prolongations which is not seen when the animal is preserved in formalin or alcohol. The hook and manubrium could not be made out in preserved material.

I am giving below a table in which measurements of the various diagnostic characters from 10 living specimens of one day's collection are given. The length and breadth of the animal in an expanded condition under a coverslip were measured with the aid of a binocular, while the cirri were measured in a similar condition under the low power of the microscope. The other measurements were taken while the animals were in a watch glass of water. All measurements were initially taken with an eye-piece micrometer and were later converted into millimetres. The measurements of the cirri are given in microns.

The body of the animal is oblong (Plate XXVII, Fig. 2) and seems to grow to a maximum length of 8 mm. The maximum width observed is about

TABLE.

Table of Measurements of the Various Diagnostic Characters.

Specimen Number	1	2	3	4	5	6	7	8	9	10
Length of animal	2·26	2·78	4·70	5·66	5·92	6·26	6·26	6·44	6·70	7·74 mm.
Width of animal	1·74	2·00	3·22	3·04	3·40	2·50	4·69	4·00	3·80	4·80 ,,
Length of pharynx		2·18			2·78				2·52	,,
Width of pharynx		0·26			0·34 to 0·56				0·52	,,
Width of clear margin	Nil.	Nil.	0·17	0·26 to 0·47	0·17	0·17 to 0·20	0·30	0·26	0·26	0·17 ,,
Width of white streak in the mid ventral line	0·17 to 0·26	0·26 to 0·35	0·20 to 0·34		0·26 to 0·34	0·34 to 0·43	0·26 to 0·34	0·26 to 0·34	0·26 to 0·34	0·26 to 0·34 ,,
Length of parapodia A.—Base	0·12	0·26	0·43	0·34	0·30	0·26	0·44	0·43	0·44	0·30 ,,
B.—Tip	0·09	0·17	0·17	0·26	0·17	0·17	0·26	0·17	0·26	0·20 ,,
Width of parapodia A.—Base	0·17	0·30	0·34	0·43	0·30	0·26	0·44	0·44	0·44	0·34 ,,
B.—Joint	0·09	0·13	0·17	0·26	0·17	0·17	0·26	0·26	0·26	0·26 ,,
C.—Tip	0·05	0·09	0·12	0·12	0·17	0·13	0·17	0·17	0·17	0·20 ,,
Distance of parapodia from margin	0·47	0·52	0·96	1·31	1·13	1·13	1·29	1·14	1·13	1·29 ,,
Diameter of suckers	0·09	0·09	0·17	0·12	0·17	0·17	0·17	0·17	0·13	0·26 ,,
Distance of suckers from margin	0·17	0·13	0·26	0·17	0·34	0·26	0·26	0·30	0·35	0·44 ,,
Distance of cloaca from hind margin	0·34	0·43	0·69	1·04	0·78	0·70	0·70	1·15	0·78	0·87 ,,
Number of cirri	20	48	54	94	84	84	96	94	70	136 ,,
Length of cirri in μ	50	8 to 90	10 to 180	20 to 100	20 to 100	44 to 174	44 to 174	50 to 150	22 to 174	44 to 215
Width of cirri in μ	50	22 to 90				44 to 132	44 to 132		44 to 88	44 to 132

5 mm. The anterior and posterior ends of the animal in the living condition are rounded and inconspicuous notches are seen at the anterior end. But,

if the animal is pressed between two slides during fixation, in order to expand the pharynx, there appear at the anterior and posterior ends notches which vary in shape very greatly. Yet, it has been found possible to fix the animal in as life-like a condition as possible.

The dorsal surface of the animal is smooth and without crests, ridges, papillæ or warts. If the animal is irritated five projections on each side of the dorsal surface, corresponding to the parapodia could be made out. This peculiarity is seen in some preserved material also, but to my mind this seems to have no significance at all. In some preserved material wart-like projections were observed on the dorsal surface, but they lacked regularity in arrangement and occurrence and being absent in living material appear to be only results of the physiological reaction of the animal at the time of preservation.

The margin of the body is transparent in the living animal and bears 20–136 cirri (Fig. 3). In the youngest specimens observed there are only

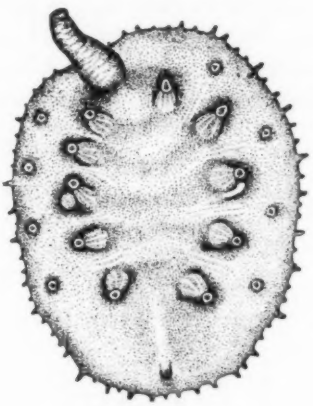

FIG. 3.

Ventral view of the animal showing the parapodia, suckers, male papillæ, etc. × 15.

twenty cirri, ten on each side. These are almost as long as the longest cirri in the largest of the specimens. They are distributed along the margin at almost equal distances, and all of them are of equal length and shape. When the animal grows older, other cirri make their appearance between these ten primary ones. No uniformity in appearance of these secondary cirri have been observed, for they may arise first in the posterior or anterior half of the animal. But the noteworthy feature is that increase in number was not observed to be limited to the right or left half of the animal. The secondary cirri are also of two types. Some of them grow to the size of

the primary ones and become indistinguishable from them, while the others remain smaller. Usually between two of the longer cirri may be observed 1–7 smaller ones. Increase in number of these structures continues throughout the period of life of the animal, but it was found impossible to correlate exactly the size of the animal with the number of cirri. The longer cirri are highly contractile and it was found difficult to fix them in an extended condition. In most preserved specimens they are almost indistinguishable from the smaller ones. It also sometimes happens that only the longer cirri are visible in preserved material, while the smaller ones appear as small knobs on the margins.

On the ventral surface (Plate XXVII, Fig. 1) there are five pairs of parapodia, four pairs of suckers, the mouth and cloacal openings. In the extended condition, the pharynx bears at its extremity a circlet of ten tentacles while when contracted, the mouth opening has the appearance of a small papilla situated a short distance from the anterior margin. There is no ventral muscular mass and a white streak, which is slightly raised up, marking the position of the main alimentary canal tube is seen in living and some fixed specimens. The cloacal opening is situated on a papilla at some distance from the posterior margin. The parapodia are well developed and are situated in almost two parallel lines. Each parapodium shows a division into a thick basal part which is conical and a short rod-like distal part. This division, however, appears to be only external, and no wall has been observed to separate the basal from the distal part (Fig. 4). The distance

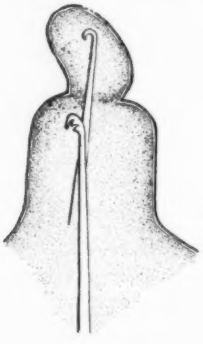

FIG. 4.

A parapodium showing the hook and the manubrium. × 100.

between the last pair of parapodia and the hind margin is almost double that between the first and the anterior margin. The hook and manubrium are shown in Fig. 4. A difference in the disposition of the parapodia has

been observed between living and fixed materials. The parapodia which are seen as conical protuberances in the living animal, appear in fixed material as if situated in small depressions. This is clearly an effect of preservation. Parapodia occurring in small depressions have been employed by Graff (1884) as a criterion to distinguish between *M. brevipes* and *M. pallidum*. Only examination of living *M. brevipes* could settle how far this characteristic is of normal occurrence and hence valid. The male papillæ are situated very near the third parapodia. In the living animal they are inconspicuous but if slightly pressed between two slides they become prominent. In preserved specimens, usually, the papilla is hidden by the parapodium which under pressure becomes directed towards the margin of the body.

In the living and fixed specimens the suckers are prominent and in the former their contractions could be observed. They are slightly oval and situated very near the margin.

In some specimens which are uniformly yellowish orange the alimentary canal diverticula could be very clearly made out. There appear to be only two main diverticula (Fig. 5) the branches of which are distributed through-

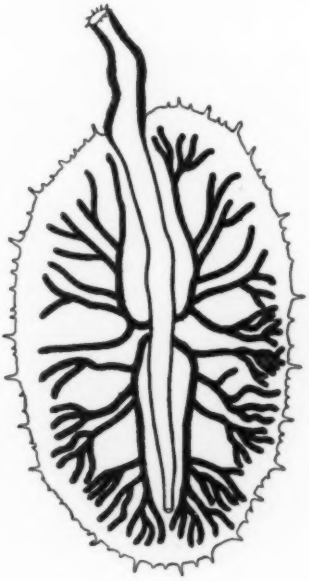

FIG. 5.

Alimentary canal diverticula as seen in a living specimen. × 15.

out the body. The lateral diverticula, especially those lying near the margin have a reddish colour and their cells contain fat droplets.

Acknowledgment.

My thanks are due to Professor R. Gopala Aiyar for his kindness and encouragement.

REFERENCES.

Atkins, D. .. "Report on the Myzostomida collected by Mr. F. A. Potts in the Torres Strait together with a description of a species obtained by Prof. J. Stanley Gardiner from Maldives," *Proc. Zool. Soc. Lond.*, 1927, 339–57.

Clark, A. H. .. "A Monograph of the Existing Crinoids," *Bull. U.S. Nat. Mus.*, 1921, No. 82.

———— .. "On a Collection of Crinoids from the Indian Ocean and the Bay of Bengal," *Rec. Ind. Mus.*, 1932, **34**, 551–66.

von Graff, L. .. "Verzeichniss der von den United States Coast Steamers *Hassler* und *Blake* von 1867 zu 1879 gesammelten Myzostomiden," *Bull. Mus. Comp. Zool.*, 1883–85, **9**, 125–35.

———— .. "Report on the Myzostomida collected during the voyage of *H.M.S. Challenger* during the years 1873–76," *Rep. Chall. Exped.*, **10**, Pt. 27, 1–80.

McClendon, J. F. .. "New Marine Worms of the Genus *Myzostoma*," *Proc. U.S. Nat. Mus. Smithsonian Inst. Wash.*, 1907, **32**, 63–65.

575-38 Printed at The Bangalore Press, Bangalore City, by G. Srinivasa Rao, Superintendent, and Published by The Indian Academy of Sciences, Bangalore.

FIG. 1.
Dorsal view of the animal.

FIG. 2.
Ventral view of the animal.

FOUR CASES OF ABNORMALITIES IN THE BLOOD VASCULAR SYSTEM OF THE COMMON INDIAN FROG (*RANA TIGRINA* DAUD.).

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[Communicated by Dr. M. B. Mirza, Dr. Phil. Nat. (Ffm.), F.R.M.S. (Lond.).]

Introduction.

To the best of the author's knowledge, with the exception of a case of an abnormal anterior abdominal vein recorded by Bhaduri[1] in a female specimen, no case of abnormality in the vascular system of *Rana tigrina* has yet been recorded. The present communication is based upon three specimens:

(*a*) One specimen showing an arterial abnormality;

(*b*) the second exhibiting an anterior venous abnormality; and

(*c*) the third with an anterior venous and a post-caval abnormality.

All three specimens were found during class dissections and were otherwise perfectly normal. Each of these specimens was recorded in a lot of thirty-two frogs. Attention was drawn towards these abnormalities by the students performing the dissections, after which the rest of the dissection was completed by the author.

Curiously enough all the three specimens were adult females and the one recorded by Bhaduri was also a female. Though this data is not enough to form any definite conclusion regarding the occurrence of vascular abnormalities in *R. tigrina* with reference to the sex, it may at least be conjectured that such a relation is not a mere chance occurrence. In his valuable memoir O'Donoghue[2] has recorded and brought up-to-date all cases of abnormalities in the order *Anura*. From his data it is clear that in the common European frog (*Rana temporaria*) abnormalities occur with greater frequency in males than in females, and that in the anterior venous system with a few exceptions it is the right anterior vena cava which fails to develop. In the present specimens also it is the right anterior vena cava which is absent but the sex is female in both the cases.

In *R. tigrina* either the abnormalities in the vascular system are very rare, or else, they have not been observed.

An Arterial Abnormality.

Specimen A (*Fig.* 1).—Two abnormal branches arising close together from the systemic arch and one of the branches of the larger vessel joining the external carotid (lingual) artery.

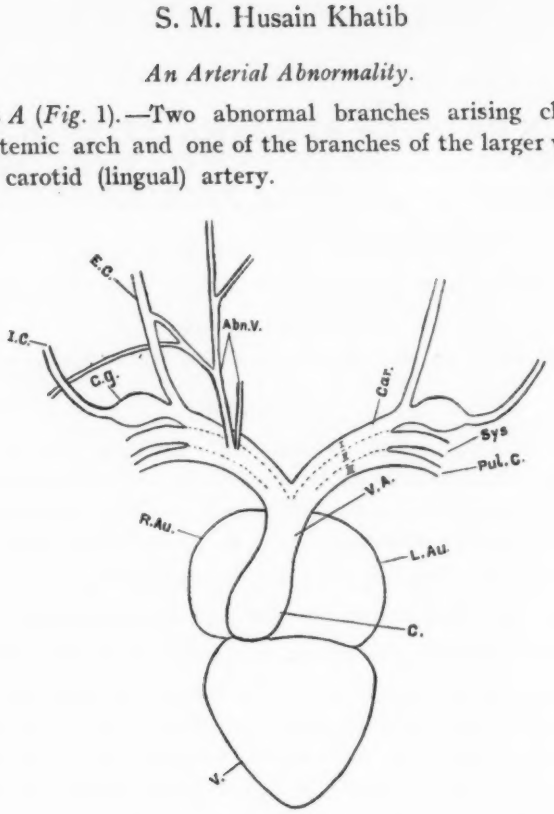

FIG. 1.

The specimen under consideration is an adult female (the word adult is used to indicate that the individual has reached sexual maturity but not the full size). When attention was directed to this specimen, all the main arterial trunks had been exposed and to a certain extent cleared, consequently the finer branches of these abnormal vessels were severed and hence could not be traced further. So far as is known no such abnormality has been recorded before in the *Anura*.

Two vessels, one very small, arise close together from the right systemic arch beyond the point where it diverges from the truncus arteriosus. The smaller vessel was cut close to its origin and hence it could not be traced any further. The other vessel was fairly large but somewhat narrower in calibre than the internal carotid artery. After pursuing a straight course for a short distance, it gives rise to two branches one of which proceeds further forwards parallel to the main axis of the animal in the muscles of the ventral

surface of the head and bifurcates into two branches both of which were cut down slightly beyond the point of bifurcation. The other main branch of this vessel runs obliquely to the right side upto the external carotid (lingual) artery where it bifurcates into two branches one anterior and the other posterior. The anterior branch joins the external carotid artery and the posterior branch passes dorsad to the external carotid and the internal carotid arteries in a postero-lateral direction. Further distally it was cut off.

These vessels were dissected under a dissecting microscope. The two vessels arose distinctly from the systemic trunk, as careful tracing showed that they passed ventrad to the carotid trunk and ended at the anterior half of the systemic arch. As sufficient blood was retained in the external carotid artery it was found that after occlusion of this vessel below the point where it was joined by the abnormal branch, if it was pressed above this point the blood could be made to flow into the abnormal vessel. The normal direction of the flow of blood could not be ascertained in this abnormal branch as the circulation had come to a stand-still by the time the dissection was completed.

No explanation for this abnormality can be offered either on ontogenetic or on phylogenetic grounds.

Venous Abnormalities.

Abnormalities in the venous system of vertebrates are much more common than in the arterial system. The development of the anterior veins is simple and the abnormalities do not throw much light either on the development or on the phylogeny. The abnormality of the post-caval vein recorded here can be explained in the light of the developmental history and will be dwelt with in its proper place.

Specimen B (*Fig.* 2).—An adult female *Rana tigrina*. The right anterior vena cava is absent. From the junction of the subclavian, innominate, and external jugular veins of the right side, which are normally constituted, there runs an anastomosing vessel to join the left external jugular vein at a point half way up between its junction with the innominate and the subclavian veins of this side, which are normally constituted, and the union of the lingual and the mandibular veins. The left external jugular vein is larger than that of the right side. The left anterior vena cava, which is the only vessel left to collect blood from the anterior region of the body, is much larger than that of a normal specimen of the same size. These enlargements of vessels on the left side, in the absence of the right anterior vena cava,

are to be expected, as the anastomosing vessel first joins the external jugular vein of this side which is the only channel for receiving all the blood from

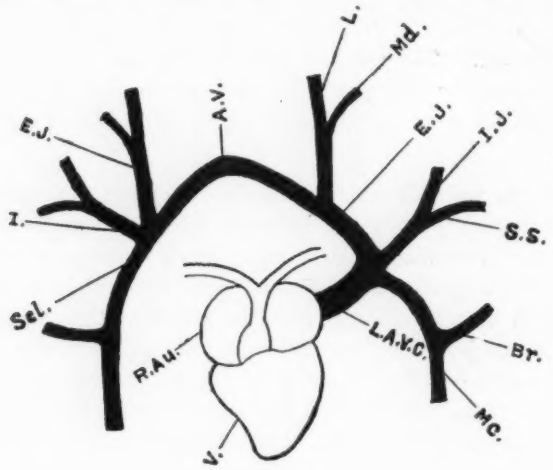

FIG. 2.

the right side, and consequently becomes enlarged. The enlargement of the left anterior vena cava can also be explained on the same ground.

So far this type of arrangement of the anastomosing vessel in the absence of one of the anterior venæ cavæ has not been recorded in the *Anura*. Shore[9] has recorded an abnormality in *R. temporaria* (sex not stated) in which an anastomosing vessel runs from the junction of the right external jugular, innominate, and subclavian veins to the junction of the left external jugular, innominate, and subclavian veins, and the anterior vena cava of the right side is absent. This abnormal vessel (anastomosing vessel) lies much closer to the heart and possesses two prominent dilatations upon it from which Shore concludes that " the blood did not have an easy passage through it.....for at the point of junction of the innominate* with the left precaval there would be two currents of blood passing in opposite directions, uniting into a common channel." The author does not think that this could be the proper explanation for the swellings, for, in all cases where one of the caval veins is absent the blood is conveyed through a transverse anastomosing vessel from one side of the body to the persistent caval vein of the other side and hence there would be " two currents of blood passing in

* This is the name that Shore gives to this anastomosing vessel, believing it to be a homologue of the innominate vessel in man and other higher mammals.

opposite directions" but in no case such swellings in the course of the anastomosing vessel have been recorded except Figs. 1 and 2, of O'Donoghue.[7] Some factors other than the mere pressure of blood appear to be responsible for this, or else, it may be only a casual occurrence without any special significance. Regarding this vessel, figured by Shore, O'Donoghue[5] says, " It is also open to question whether the vessel in this specimen is to be regarded as homologous with the anastomosis in all the other examples, for it lies in quite a different position." In another paper published later,[7] he records an abnormality in a male *R. temporaria* where there are two anastomosing vessels running from the right to the left side, one anterior and the other posterior to the glottis. The position of the posterior vessel and its relationship with the veins of the two sides is more or less identical with that of Shore's specimen and I do not think that O'Donoghue's doubts regarding the homology of the anastomosing vessel of Shore with the anastomosing vessels in other examples are well-founded. The specimen described by Grove and Newell[3] does not possess the right anterior vena cava and the anastomosing vessel runs from the point of junction of the left external jugular, innominate, and sub-clavian veins to the distal end of right external jugular vein. But in the present specimen the anastomosing vessel runs from the point of junction of the right external jugular, innominate, and sub-clavian veins to the distal end of the left external jugular vein.

Other vessels, as far as could be seen, in this and the following specimen, except otherwise mentioned, were normal, and the specimens were also quite normal. The heart had two auricles, the pulmonary veins opened into the left auricle, but the sinus venosus was asymmetrical owing to the absence of one anterior caval vein.

Specimen C (*Fig.* 3).—This is an adult female *Rana tigrina* in which the right anterior vena cava is absent and the inter-renal vein is abnormal. The veins on the left side are normally constituted with the exception of the external jugular vein and the left anterior vena cava which are both slightly larger than those of a normal specimen of the same size. On the right side the sub-clavian and the innominate veins are normally constituted, a transverse anastomosis connects the external jugular vein of this side with that of the left and during its course receives the mandibular and the lingual veins which do not unite but open separately into it. This specimen resembles O'Donoghue's[5] example 10, on the whole, but it differs from it in showing no indication of an extension of the right anterior vena cava upto the pericardium ending in a blunt process. Consequently, the curve here is a smooth one.

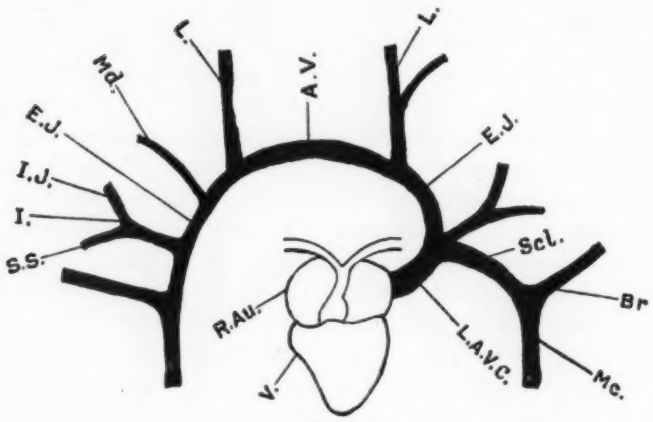

FIG. 3.

This very specimen possesses an abnormal post-caval vein (Fig. 4). The left kidney is markedly smaller than the right although its arterial as well as venous blood supply is normal. In a normal specimen the inter-renal portion of the post-caval vein extends up to a point slightly in front of the posterior limit of the kidney and generally receives six renal veins on either side. The first renal vein also receives a tributary from the ovary

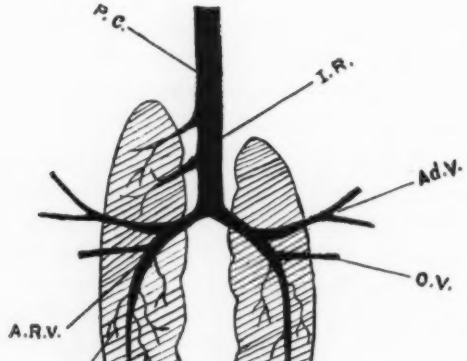

FIG. 4.

and one from the fat body ; one more tributary from the same organ generally joins the third renal vein, but this second ovarian vein may directly open into the inter-renal vein.

In the specimen under discussion the inter-renal portion of the post-caval vein does not extend beyond the anterior half of the two kidneys. At its extreme posterior limit it is joined by two abnormally long renal veins each of which receives a vein from the fat-body, one from the ovary of its side, and a few small revehent tributaries. The left kidney does not possess any other renal vein except this abnormally long vein. The right kidney gives off two more renal veins. Hence the inter-renal vein is formed by three renal veins on the right side and one on the left side. Beyond the limits of the kidneys the inter-renal vein proceeds forwards as the post-caval vein and its course upto the sinus venosus is perfectly normal. As described by Shore[9] in *R. temporaria* the post-caval vein in the adult frog is composed of three embryonic portions, *viz.*,

(i) the inter-renal vein, formed by the fusion of the posterior cardinal veins behind the origin of the cœliaco-mesenteric artery from near the point of junction of the two systemic aortæ ;

(ii) part of the oblique portion of the right posterior cardinal vein behind the point where it is joined by a backward extension of

(iii) the hepatic vein, which in its turn is derived from the left vitelline vein.

The oblique portion of the left posterior cardinal vein beyond its point of fusion with the right posterior cardinal vein degenerates after the atrophy of the pronephros and that of the right posterior cardinal anterad of its junction with the hepatic vein also meets with the same fate simultaneously. Hence the anterior portion of the post-caval vein is formed by the transformation of the vitelline vein, the middle portion by the right posterior cardinal vein, and the posterior portion by the fusion of the right and left posterior cardinal veins. The caudal continuation of the mesonephric channel (now the inter-renal vein) also degenerates with the absorption of the tail. Goette's (1890) opinion, cited by Gaupp (1899) differs from this to some extent and is as follows :—" Der hinterste (Urnierenabschintt) entsteht durch Verschmelzung der zwischen den beiden Urnieren gelagerten Abschnitt der Cardinalvenen, zu dem cordersten wandelt sich der Rest der rechten Darmlebervene um, und der mittlere Abschnitt, der diese beiden Theile unter einander verbindet, entsteht als eine Neubildung von dem vordersten Abschnitt her. Hinten verbindet er sich mit der rechten *V. cardinalis*, kopfwarts von der Stelle, bis zu der beide *V v. cardinales* under einander verschmolzen sind" (pp. 379–80, Gaupp's *Anat. d. Frosches.*) In the light of the developmental history, the present abnormality can be explained in one of the three ways :

1. The two posterior cardinal veins failed to unite in the middle line during their course through the middle mesonephric region, and the abnormally long renal veins may represent the persistent right and left posterior cardinal veins.

2. At the time of degeneration of the caudal vein a greater portion of the fused posterior cardinal veins also disappeared along with it and to compensate for the loss the last renal veins have elongated to such a great extent towards the posterior region.

3. The left posterior cardinal vein did not develop at all, or else, degenerated at a very early stage in the region of the mesonephros and when the left mesonephric tubules began to develop, a diverticulum was given off from the right posterior cardinal vein to collect blood from this kidney. This hypothesis is further supported by the fact that the left kidney has no renal veins except the one mentioned above and is much smaller in size.

The only explanation that can be offered for the short size of the kidney is that due to some unknown reasons the anterior kidney tubules failed to develop. This, in some way, may be correlated with the loss of the left posterior cardinal vein if the third hypothesis mentioned above is correct. No great significance, however, can be attached to the smaller size of one of the kidneys, for, in many frogs with a normal blood-supply to the kidneys, one of the kidneys may be smaller than the other.

Summary.

For the first time abnormalities in the anterior venous and the arterial system have been recorded in the *common Indian frog*. The present communication is based upon three frogs, all adult females. No explanation can be offered in the light of the developmental history or on phylogenetic grounds regarding the arterial abnormality and the anterior venous abnormality. Three explanations for the abnormal post-caval vein have been put forward on ontogenetic grounds. All the three specimens were found each in a lot of thirty-two frogs during class dissections.

Acknowledgments.

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REFERENCES.

1. Bhaduri, J. L. .. "Abnormal Anterior Abdominal Veins in an Indian Frog, *Rana tigrina* Daud., and in an Indian Toad, *Bufo melonostictus* Schneid; together with a Review of the recorded cases of Abnormalities of the Anterior Abdominal Veins," *Jour. Dept. Sci., Calcutta*, 1929, **10**.
2. Goodrich, E. S. .. *Structure and Development of Vertebrates*, London, 1930.
3. Grove, A. J., and Newell, G. E. "A case of abnormality in the venous system of the Common Frog *R. temporaria*," *Jour. Anat.*, 1934, 68.
4. Marshall, A. M. .. *Vertebrate Embryology*, London, 1893.
5. O'Donoghue, C. H. .. "Abnormalities in the blood vascular system of the *Anura*," *Trans. Roy. Soc. Edinburgh*, 1931, **57**.
6. ———— .. "Abnormalities in the blood vascular system of four frogs," *Anat. Anz.*, 1933, Bd. **75**.
7. ———— .. "Further abnormalities in the blood vascular system of frogs," *Jour. Anat.*, 1935, **70**.
8. Shore, T. W. .. "Abnormal veins in the frog," *Jour. Anat. Phys.*, 1901, **35**.
9. ———— .. "On the development of the Renal Portals and fate of the Posterior Cardinal Veins in the Frog," *Indem.*, 1902, **36**.
10. Woodland, W. N. F. .. "On the Renal Portal System (Renal Venous Meshwork) and kidney excretion in Vertebrata," *Jour. Proc. Asiatic Soc. Bengal*, 1922, **18**.

LIST OF ABBREVIATIONS.

Abn.V.	Abnormal vessel arising from the systemic.	*L.Au.*	Left auricle.
Ad.V.	Vein from the fat-body.	*L.A.V.C.*	Left anterior vena cava.
A.R.V.	Abnormal renal vein.	*Mc.*	Musculo-cutaneous vein.
A.V.	Transverse anastomosing vessel.	*Md.*	Mandibular vein.
Br.	Brachial vein.	*O.V.*	Ovarian vein.
C.	Conus.	*P.C.*	Post-caval vein.
Car.	Carotid trunk.	*Pul.C.*	Pulmo-cutaneous trunk.
C.g.	Carotid gland.	*R.Au.*	Right auricle.
E.C.	External carotid artery.	*Rv.T.*	Revehent tributary.
E.J.	External jugular vein.	*Scl.*	Subclavian vein.
I.	Innominate vein.	*S.S.*	Sub-scapular vein.
I.C.	Internal carotid artery.	*Sys.*	Systemic aorta.
I.J.	Internal jugular vein.	*V.*	Ventricle.
I.R.	Inter-renal vein.	*V.A.*	Ventral aorta (Truncus arteriosus).
L.	Lingual vein.		

STUDIES IN SORGHUM—THE NON-AURICULATE AND E-LIGULATE CONDITION.

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Received June 1, 1938.

The occurrence of the non-auriculate and e-ligulate condition has been reported in the leaves of sorghum. The character responsible for this condition has been designated *lg*, the normal auriculate and ligulate condition being *Lg*. *Lg* is a simple dominant to *lg* (Rangaswami Ayyangar, *et al*, 1935).

An intensive examination of the non-auriculate families has since been made, both in pure lines and in families derived from crosses made between the normal auriculate and these special non-auriculate lines. Many interesting points have been met with throwing helpful light on the homology of ligule and auricle and the other parts of the plant.

The effect of this non-auriculate condition in inducing the erectness of the leaf-blade in the seedling and in the adult plant has been recorded, (Rangaswami Ayyangar, *et, al* 1935) (Fig. 1). The most noticeable effect of the non-auriculateness is however to be seen in the reproductive parts of the plant. Nilsson-Ehle working on *Avena* noted a general relationship between the panicle shape and the non-auriculate condition of the leaf (Matsuura, 1933).

In the non-auriculate families of sorghum there is an absence of the cushiony pulvinus at the base of both the main and secondary panicle branches and in their axils. The branches seem as it were, to lead off directly from the stalk without the help of the specialised pulvinus. This abrupt branching out results in a relatively less thick and more tapering condition of the central stalk of the panicle (Fig. 3).

The narrowing of the stalk and the free and direct outflow of the panicle branches from the central stalk has naturally an effect on the extent of the spikelet-free area at the base of the panicle branch and the angle which the branch could safely make with the central stalk. In each family, relatively

to the auriculate plant, the non-auriculate plant has a shorter spikelet-free stalk. It is noticed that whereas this spikelet-bearing area in both the groups is about the same, the difference is only in the free stalk between the spikelet-bearing area and the central stalk. This phenomenon, *viz.*, the absence of the pulvinus and the shortening of the spikelet-free area in the main branches of the panicles, is repeated in the case of the side branches arising from the main branch. The effects of the non-auriculate condition detailed above, are naturally noticed very graphically in the lowest and longest branch of the panicle.

In the Broom-corn family, A.S. 3698, in which the segregation of the seedlings is given in the article quoted above, there was available an adult population of 104 auriculate and 33 non-auriculate plants. From this family a third generation was raised. There was again a segregation for this character with 51 auriculate and 19 non-auriculate plants. All these 70 plants were examined in detail. It was noted that the average length of the spikelet-bearing area in the lowest and longest branch in auriculate plants was 16·7 cm. In non-auriculate plants it was 16·8 cm., there being practically no difference between the two groups as far as the spikelet-bearing area is concerned. The marked difference however is in the free stalk below the spikelet-bearing area (Fig. 2). In the non-auriculate lots the average length for the 19 plants is 5·0 cm., there being 6 plants practically stalk-less. In the auriculate group of 51 plants the average length of free stalk was as much as 29·5 cm. The result of this shortening of the free stalks in non-auriculate families and the absence of pulvinus is, that the branches are adpressed to the central axis of the panicle and make the head very compact, crowded with spikelets right from the very base of the earhead and to the very base of each of the branches. Fig. 4 illustrates this condition in an e-ligulate selection from a Broom-corn-Feterita cross. A corresponding shortening and crowding is also in evidence in the side branches. This over-crowding in the interior of the panicle results in many infertile spikelets in such heads and does not contribute to selection and survival value in cultivation (Fig. 4).

These observations have been made on Broom-corn, a sorghum that owes its individuality to the longest free stalk in the panicle branch, an attribute which has singled it out for the making of brooms. It is interesting to note that the loss of the gene responsible for auriculateness should result in the creation of a " Broom-corn " with no broom in it (Fig. 2). After this experience it looks as if the panicle branch has two well-defined portions, *viz.*, the spikelet-bearing area and the free stalk below it, each of which being influenced by separate genetic factors.

Summary.

The occurrence of the non-auriculate and e-ligulate condition and its repurcussions on the earhead throw light on the homology between the leaf and the earhead. In non-auriculate and e-ligulate families, the leaves are more erect and the panicle branches likewise. With the suppression of the auricle and ligule there is an absence of the pulvinus and a shortening of the spikelet-free area in the panicle branches and branchlets. This leads to a choking overcrowding of the spikelts on the earhead and consequent risk of sterility. In highly evolved sorghums with auricle and ligule, the presence of the pulvinus and pushing away of the grain-bearing area from the central axis have resulted in producing an economic earhead. These observations are wider in their import in that they throw light on the evolution of the gramineæ.

REFERENCES.

1. Matsuura, H. .. .. *Bibliographical Monograph on Plant Genetics*, II Edition, Revised and enlarged, 1933.

2. Rangaswami Ayyangar, G. N., *et al.* *Ind. J. Agric. Sci.*, 1935, **4**, 532-41.

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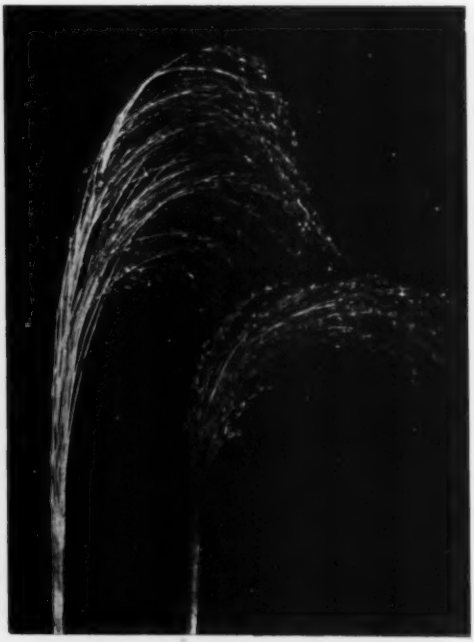

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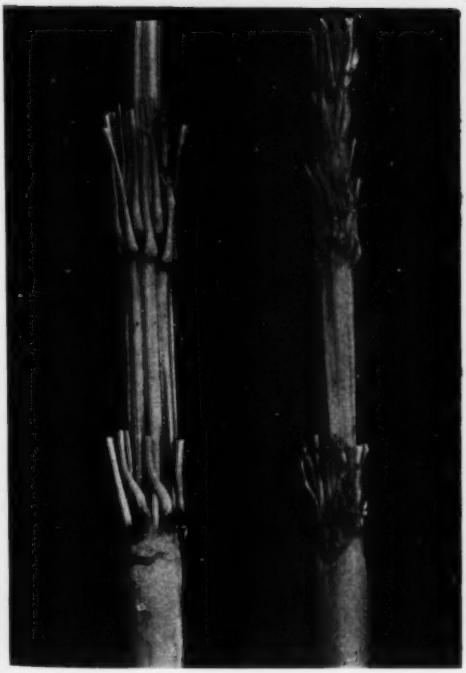

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1. Seedlings of auriculate and non-auriculate plants.
2. The corresponding earheads of the above plants in Broom-corn.
3. The central stalk of these earheads (thick and thin, pulvinate and non-pulvinate).
4. An over-crowded and much sterile earhead from a non-auriculate and e-ligulate grain sorghum.

BRACHYMERIA EXCARINATA, GAHAN (FAMILY CHALCIDIDÆ) A PUPAL PARASITE OF *PLUTELLA MACULIPENNIS*, CURTIS IN SOUTH INDIA.

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Introduction.

Plutella maculipennis Curtis commonly known as the Diamond-back moth is a pest of cruciferous plants, especially cabbage and cauliflower in many parts of the world. In the course of the studies of this pest in South India the authors have for the first time observed two natural enemies, *viz.*, *Brachymeria excarinata* Gahan and *Tetrastichus sokolowskii* Kurdj, parasitising the pupa and larva respectively. The present paper gives an account of the former.

Life-History of the Pest.

A brief account of the pest is attempted here so as to point out clearly the activities of the parasite. Adult moths are greyish brown in colour and measure about 12–14 mm. Eggs are laid singly on the underside of the leaves of the host plant. They are greenish yellow in colour and measure 0·5 mm. The eggs hatch in 3 days and the tiny caterpillars which emerge from the eggs are pale white in colour with a brownish head. They feed on the leaves of the host plant and grow in size. When full fed they are dull green in colour and about 8 mm. long and 1·5 mm. broad. Before pupation they construct lace-like cocoons of white silk and pupate inside these. The larval period is about 8-11 days. The pupa is 5-6 mm. long and 1·5 mm. broad. The pupal period is about 4 days. The whole life-cycle from egg to adult in September and October 1937 under Coimbatore conditions is about 15–18 days. The temperature and humidity are noted in Table VI. Dusting with pyrethrum powder has been found to be a very effective remedy against the pest. The parasites mentioned above are also found to play an important part in the reduction of the numbers of the pest. Marsh[1] has given a detailed account of the moth in his paper on "Life-history of *Plutella maculipennis*, the Diamond-back moth".

History of the Parasite.

Brachymeria excarinata belongs to sub-family Chalcidinæ, family Chalcididæ. It was first recorded from the Philippine Islands as parasitic on

Cnaphalocrocis medinalis and described by Gahan[2] in his paper on " A Second lot of parasitic Hymenoptera from the Philippines ". As far as the authors are aware this is the first time that the parasite is noted in India although Dutt[3] mentions in his paper on " An annotated list of Ichneumonidæ in Pusa collections " two other parasites *Angitia fenestralis* Homlg. and *Diadromus collaris* Grav. on *Plutella* from North India.

Description of the parasite.—Gahan's description of the parasite is given below :—

" The carina separating the face from the cheeks runs straight to the eye margin and is without the backward directed branch present in most members of the genus. In this respect it agrees with *ovata* Say, but it differs from that species by lacking any suggestion of a tooth or tubercle on the underside of hind coxæ, the abdomen is more acuminate at apex, and the sixth tergite is less coarsely sculptured. Both *hirtifrons* Ashmead and *prodeniæ* Ashmead lack the carina on the cheek. The former differs from the new species by being far less coarsely punctate on the dorsum of the thorax, the mesoscutum and scutellum being finely shagreened and shining with widely separated, small, round punctures ; by having the first tergite distinctly finely and closely punctate ; and by having the abdomen very blunt at apex. The species *prodeniæ* is much smaller than the new species, its sixth tergite is not longer than the fifth and the hind tibiæ are almost entirely black.

Female :—Length 4 mm. Occiput shagreened ; vertex umblicitely punctate ; frons lateral of the antennal groove, face, cheeks, and temples rugulose ; clypeus shining with a few shallow punctures ; antennal groove polished within ; antennal flagellum nearly of the same thickness throughout ; funicle joints subequal in length and quadrate, none of them transverse ; pronotum above, mesoscutum, scutellum and axillæ with close umbilicate punctures, the scutellum margined at apex but not bilobed ; propodeum with coarse irregular rugose-reticulate sculpture ; submarginal vein nearly two and one-half times as long as marginal ; post-marginal a little less than half as long as marginal ; hind femora with nine small teeth on the ventral margin, the three nearest base of femora considerably broader but not much longer than those toward apex ; abdomen as long as the thorax, pointed ovate, not bluntly rounded at apex as in many species ; first tergite polished impunctate ; second to fifth shining but weakly punctate or shagreened over most of their surfaces ; sixth sub-opaquely shagreened but without coarse punctures, fully twice as long as the fifth tergite and about twice the length of the seventh ; tip of ovipositor barely showing.

Black ; antennæ black, the apex of club brownish ; tegulæ, small apical spot on all femora, front tibiæ outwardly for their whole length, middle

tibiæ at base and apex, and incomplete broad band on hind tibiæ near base and another at apex, and all tarsi pale lemon yellowish, the apices of tarsi more or less brownish ; venter of abdomen toward apex more or less brownish ; wings hyaline, the venation dark brown."

Habits of the Parasite.

The adult parasite emerges by biting a small hole at the head end of the host pupa. Copulation takes place soon after emergence of the parasites and eggs are laid even on the day of their emergence. The female first feels the presence of the host pupa with her antennæ and then gets upon it generally on the dorsal side and punctures its body with her ovipositor. While doing so, she inserts her hind legs into the netted cocoon of the host to get a firm hold of the pupa, inserts her ovipositor into it and drops her eggs.

Table I gives the egg-laying records of a mated female when only one pupa was given daily for oviposition. It shows that 213 eggs were laid by the wasp and 16 was the maximum number for a day. The parasite has got the habit of laying more than one egg if only one pupa is given and in

TABLE I.

Table showing the number of eggs laid by a female of Brachymeria excarinata. (*Only one pupa exposed daily.*)

Date of exposing the pupa	Number of eggs found in the pupa	Date of exposing the pupa	Number of eggs found in the pupa	Date of exposing the pupa	Number of eggs found in the pupa
1-11-1937	..	13-11-1937	9	25-11-1937	11
2-11-1937	3	14-11-1937	8	26-11-1937	6
3-11-1937	8	15-11-1937	8	27-11-1937	4
4-11-1937	9	16-11-1937	..	28-11-1937	6
5-11-1937	12	17-11-1937	11	29-11-1937	5
6-11-1937	3	18-11-1937	9	30-11-1937	3
7-11-1937	..	19-11-1937	3	1-12-1937	3
8-11-1937	16	20-11-1937	16	2-12-1937	4
9-11-1937	3	21-11-1937	5	3-12-1937	4
10-11-1937	10	22-11-1937	6	4-12-1937	2
11-11-1937	11	23-11-1937	..	5-12-1937	..
12-11-1937	10	24-11-1937	5		

Total number of eggs for 35 days .. 213

TABLE II.

Statement of oviposition of six females of Brachymeria excarinata.

(*More than one pupa exposed daily.*)

Number of days the female lived	Pair No. 1				Pair No. 2				Pair No. 3				Pair No. 4				Pair No. 5				Pair No. 6			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
1st Day	8	8	..	..	8	8	..	..	4	3	1	..	15	12	2	1	20	18	2	..	20	10	..	10
2nd ,, ...	6	4	2	..	8	4	4	..	4	..	2	2	15	10	..	5	15	14	1	..	15	4	2	9
3rd ,, ...	3	1	2	..	6	2	3	1	3	..	2	1	20	12	..	8	12	9	1	2	15	7	3	5
4th ,, ...	3	..	1	2	3	1	1	1	4	..	4	..	18	9	1	8	10	5	4	1				
5th ,, ...	4	1	2	1	3	..	3	..	4	..	3	1	16	10	2	4	15	5	..	10				
6th ,, ...	4	1	2	1	4	..	4	..	3	..	3	..	20	10	..	10	15	8	1	6				
7th ,, ...	3	1	2	..	4	..	4	..	3	..	3	..	20	14	..	6	10	3	3	4				
8th ,, ...	3	..	3	..	3	..	3	..	5	..	3	2	15	12	..	3	12	2	3	7				
9th ,, ...	5	1	3	1	3	..	3	..	3	..	3	..	10	7	..	3								
10th ,, ...	3	..	1	2	4	..	4	..	3	..	3	..	8	5	1	2								
11th ,, ...	3	..	2	1	3	..	3	..	3	..	3	..	15	6	3	6								
12th ,, ...	3	2	1	..	3	..	3	..	3	2	1	..	8	1	..	7								
13th ,, ...	2	..	2	..	3	..	3	..	5	..	3	2	10	5	1	4								
14th ,, ...	5	1	..	4	2	..	2	..	3	..	3	..												
15th ,, ...	3	..	..	3	4	..	1	3	8	1	6	1												

	16th ,,	..	..	8	1	2	5	3	..	1	2																	
B2	17th ,,	..	..	8	3	4	1	8	..	4	4																	
	18th ,,	..	..	12	4	8	..	8	2	5	1																	
	19th ,,	..	..	14	2	8	4	12	8	4	..																	
	20th ,,	..	..	20	20	..	..																					
		TOTAL	..	120	50	45	24	92	25	55	12	58	6	43	9	190	113	10	67	109	64	15	30	50	21	5	24

A = Number of pupæ exposed.

B = ,, ,, moths emerged.

C = ,, ,, pupæ shrunk.

D = ,, ,, ,, from which parasites emerged.

TABLE III.

Longevity records of Brachymeria excarinata.

Serial No.	Egg laying parasites with food				Parasites not laying eggs with food				Parasites without food			
	Emerged on	Died on	Sex of the adult	No. of days lived	Emerged on	Died on	Sex of the adult	No. of days lived	Emerged on	Died on	Sex of the adult	No. of days lived
1	26—8–1937	29–10–1937	M	34	8—9–1936	26–10–1936	F	48	14—1–1937	18—1–1937	F	4
2	26—8–1937	14—9–1937	F	19	9—9–1936	28–10–1936	F	80	16—1–1937	18—1–1937	M	2
3	29—8–1937	16—9–1937	M	18	10—9–1936	14–12–1936	F	95	16—1–1937	19—1–1937	F	3
4	29—8–1937	14—9–1937	F	16	13—9–1936	27–11–1936	F	75	16—9–1937	18—9–1937	F	2
5	29—8–1937	17—9–1937	M	19	13—9–1936	15–12–1936	M	93	29—9–1937	3–10–1937	F	4
6	29—8–1937	4—9–1937	F	6	14—9–1936	11–12–1936	F	88	29—9–1937	3–10–1937	F	4
7	29—8–1937	28—9–1937	M	30	25–11–1936	18–12–1936	M	23	30—9–1937	2–10–1937	F	2
8	29—8–1937	3—9–1937	F	5	22–11–1936	12—3–1937	F	110	30—9–1937	3–10–1937	F	3
9	30—8–1937	29—9–1937	M	30	22–11–1936	7—2–1937	M	77	30—9–1937	3–10–1937	F	3
10	30—8–1937	16—9–1937	F	17	13–12–1936	29—1–1937	F	47	2–10–1937	4–10–1937	M	2
11	7—9–1937	17—9–1937	F	10	20—9–1937	19–10–1937	F	29	27–10–1937	29–10–1937	M	2
12	9—9–1937	27—9–1937	M	18	17–12–1936	21—1–1937	M	35	10–10–1937	13–10–1937	M	3
13	9—9–1937	1–10–1937	F	22	18–12–1936	8—2–1937	F	52	11–10–1937	12–10–1937	M	1
14	13—9–1937	25—9–1937	M	12	21–12–1936	27—1–1937	F	37	11–10–1937	12–10–1937	M	1
15	13—9–1937	2–10–1937	F	19	21–12–1936	8—2–1937	M	49	11–10–1937	12–10–1937	M	1
16	14—9–1937	1–10–1937	M	17	21–12–1936	10—5–1937	F	140	11–10–1937	12–10–1937	F	1
17	14—9–1937	30—9–1937	F	16	22–12–1936	10—2–1937	M	50	11–10–1937	13–10–1937	F	2
18	14—9–1937	24—9–1937	M	10	24–12–1936	8—2–1937	F	46	11–10–1937	13–10–1937	F	2
19	14—9–1937	4–10–1937	F	20	24–12–1936							

18	14—9–1937	24—9–1937	M	10	24–12–1936	8—2–1937	F	46	11–10–1937	13–10–1937	F	2
19	14—9–1937	4–10–1937	F	20	24–12–1936	8—2–1937	F	46	11–10–1937	14–10–1937	F	3
20	5–10–1937	15–10–1937	M	10	4—2–1937	4—4–1937	F	59	11–10–1937	14–10–1937	M	3
21	5–10–1937	18–10–1937	F	13	5—2–1937	7—4–1937	F	61	11–10–1937	14–10–1937	F	3
22	5–10–1937	16–10–1937	M	11	5—1–1937	29—1–1937	M	25	11–10–1937	14–10–1937	F	3
23	5–10–1937	15–10–1937	F	10	7—9–1937	29—9–1937	M	52	11–10–1937	14–10–1937	F	3
24	6–10–1937	27–10–1937	M	21	8—9–1937	12–10–1937	F	34	12–10–1937	15–10–1937	M	3
25	6–10–1937	18–10–1937	F	12	9—9–1937	20–10–1937	F	41	19–10–1937	22–10–1937	F	3
26	6–10–1937	30–10–1937	M	24	14—9–1937	28–10–1937	M	44	19–10–1937	23–10–1937	M	4
27	6–10–1937	14–10–1937	F	8	16—9–1937	6–11–1937	M	51	23–10–1937	26–10–1937	F	3
28	7–10–1937	21–10–1937	M	14	18—9–1937	6–11–1937	F	49	23–10–1937	26–10–1937	M	3
29	8–10–1937	20–10–1937	F	12	20—9–1937	18–10–1937	M	28	27–10–1937	29–10–1937	F	2
30	10–10–1937	24–10–1937	M	14	20—9–1937	6–11–1937	M	47	27–10–1937	31–10–1937	M	4
31	10–10–1937	23–10–1937	F	13	20—9–1937	6–11–1937	F	47				
32	13–10–1937	4–11–1937	M	22	21—9–1937	18–10–1937	M	27				
33	13–10–1937	20–11–1937	F	7	21—9–1937	6–11–1937	F	46				
34	1–11–1937	6–12–1937	F	35	4–10–1937	26–10–1937	M	23				
35	1–11–1937	8–12–1937	M	37	5–10–1937	6–11–1937	M	31				
Average longevity for males				20				44				2
Average longevity for females				14				62				3

such cases the pupa gets shrunk with the result that no parasite emerges. Consequently, the pupæ given for oviposition had to be cut open to note the number of eggs.

Table II gives the egg-laying records of 6 females when supplied with more than one pupa daily. It is found from the table that, in such cases, the parasite distributes its eggs, some pupæ having one egg and the others more than one egg. The larger the number of pupa supplied to the parasite the lesser the number of shrunken pupa and the greater the number of pupa with one egg. In three cases where 15, 15 and 20 pupæ were supplied, the maximum number of eggs per day was only 10 while the highest number obtained from Table I was 16.

Detailed studies of the parasite have also indicated that (1) a pupa is parasitised by more than one female, (2) that pupæ of all stages excepting the most advanced one are accepted for oviposition, (3) that cases of parthenogenesis are met with in the species, the progeny in such cases being males and (4) that no hyperparasites have been noted till now.

Longevity of Adults.

The longevity of records about 100 adults are given in Table III. For these studies the parasites were kept in 3″ × 1″ tubes and fed with honey solution. It will be seen from the table that in the case of a female which mated and laid eggs in captivity the maximum longevity was only 35 days while one which did not lay eggs lived as many as 140 days. The average longevity in the former and latter cases was 14 and 62 days respectively. Parasites kept without food did not live for more than 4 days.

Incidence of Parasites.

Table IV shows the percentage of parasitisation of pupæ collected from the field. This ranged from 15·9 to 59·5 the highest being in August. The

TABLE IV.

Percentage of parasitised pupæ in the field.

	August	September	October	November
No. of pupæ collected	192	168	239	54
No. of parasitised pupæ	115	25	54	11
Percentage of parasitisation	59·9	15·5	22·6	20·4

figures given below show clearly that *Brachymeria* together with *Tetrastichus* plays an important part in the reduction of the numbers of the pest.

	August	September	October	November
Percentage of parasitisation by *Brachymeria*	59·9	15·5	22·6	20·4
Percentage of parasitisation by *Tetrastichus*	18·2	49·4	46·0	68·5
Total percentage of parasitisation	78·1	64·9	68·6	88·9

Life-History of the Parasite.

Egg.—The egg (Fig. 1) is generally translucent, hardly visible to the naked eye in the fluid contents of the pupa. It is 0·46 to 0·57 mm. long and slightly curved. The egg period is more than a day and less than two days.

Grub.—The newly hatched grub is transparent and about the same length as that of the egg. The grub as it grows changes its colour to pale yellow. The fully grown grub (Fig. 2) measures from 3 to 4·5 mm. long and 1 to 1·5 mm. broad. When full fed the grub gradually loses its yellow colour and becomes pale white and pupates inside the host. The egg and larval periods vary from 6 to 8 days.

Pupa.—The pupa (Figs. 3 and 4) is thickest at the thoracic region and measures 2 mm. by 1 mm. by 1·5 mm. The newly formed pupa is pale yellow in colour. On the second day it turns pale brown and on the third day the colour deepens and on the fourth day it turns black and this colour is retained till the adult emerges. The pupal period varies from 4 to 7 days.

Total Life-cycle.

Table V gives the life-history records of 15 parasites. It will be seen from the table that the parasite completes its life-cycle in 10 to 15 days.

Other Species of *Brachymeria* in South India.

In addition to *B. excarinata* Gahan, the following species are represented in the Coimbatore collections :—*B. plutellophaga* Gir., *B. nephantidis* Gahan, *B. obscurata* Wlk., *B. euplœæ* West., and two other species of which one is new to science. *B. plutellophaga* was collected only once from the pupa of *Plutella maculipennis*.

TABLE V.

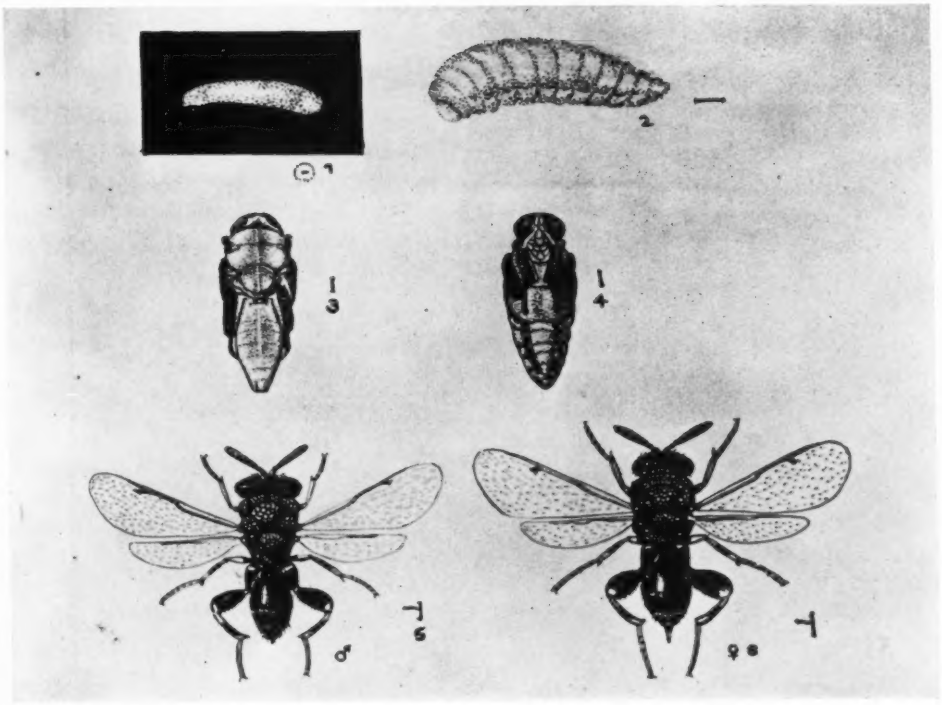
Detailed life-history records of Brachymeria excarinata.

S. No.	Date of exposing host pupæ	Date of pupation of the grub	Total pre-pupal period in days	Date of emergence of adult	Pupal period in days	Total life-cycle in days	Sex of the adult
1	20-9-1937	28—9-1937	8	5-10-1937	7	15	F
2	20-9-1937	23—9-1937	8	4-10-1937	6	14	F
3	20-9-1937	27—9-1937	7	4-10-1937	7	14	M
4	21-9-1937	27—9-1937	6	1-10-1937	4	10	F
5	21-9-1937	29—9-1937	8	5-10-1937	6	14	F
6	21-9-1937	27—9-1937	6	3-10-1937	6	12	M
7	21-9-1937	29—9-1937	8	4-10-1937	5	13	M
8	21-9-1937	28—9-1937	8	2-10-1937	4	12	F
9	21-9-1937	27—9-1937	6	1-10-1937	4	10	F
10	24-9-1937	30—9-1937	6	4-10-1937	4	10	F
11	24-9-1937	2-10-1937	8	9-10-1937	7	15	F
12	24-9-1937	1-10-1937	7	6-10-1937	5	12	M
13	24-9-1937	30-10-1937	6	4-10-1937	4	10	M
14	24-9-1937	30-10-1937	6	4-10-1937	4	10	F
15	24-9-1937	30-10-1937	6	5-10-1937	5	11	F

TABLE VI.

Temperature and humidity at which the life-history of the pest and parasite were studied.

Temperature and humidity	August	September	October	November	December
Mean minimum temperature in shade	71·2° F.	70·8° F.	70·6° F.	69·0° F.	63·9° F.
Mean maximum temperature in shade	88·7° F.	89·5° F.	86·9° F.	82·2° F.	85·0° F.
Mean humidity at 8 hours ..	74·5%	72·0%	77·4%	81·4%	74·3%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Summary.

Brachymeria excarinata Gahan is a pupal parasite of *Plutella maculipennis*. This, together with *Tetrastichus* is able to reduce the numbers of the pest considerably. The wasps are fairly long lived, the maximum longevity in one case being 140 days. Normally, the parasite lays only one egg in the pupa provided sufficient number of pupæ are present. The maximum number of eggs laid by a female has been noted to be 213. No hyperparasites have been collected so far. Cases of *parthenogenesis* have, however, been met with. The parasite takes 10–15 days to complete its life-cycle.

Acknowledgments.

The authors have to thank Mr. C. F. W. Muesebeck for kindly identifying the specimens.

REFERENCES.

1. Marsh, H. O., *Jour. Agri. Res.*, 1917, **10**, No. 1, 1–10.
2. Gahan, A. B., *Phillip. Journ. Sci.*, 1925, **27**, No. 1, 90–91.
3. Dutt, G. R., *Mem. Dept. Agric. India Ent. Ser.*, 1923, **8**, 21–27.

EXPLANATION OF PLATE XXIX.

Brachymeria excarinata.

1. Egg.
2. Grub.
3. Pupa—dorsal view.
4. Pupa—ventral view.
5. Male parasite.
6. Female parasite.

RHYNCHONELLIDS FROM THE BAGH BEDS.

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Introduction.

The Rhynchonellids from the Bagh Beds now under investigation were first identified by Duncan[5,22] with *Rhynchonella depressa* Sowerby (non d'Orbigny), from the Upper Green Sand of England and Europe. Later on Bose[7] reported, among the rhynchonellids collected by him from these strata, the presence of *Rhynchonella plicatiloides* Stoliczka, of the Trichinopoly and Ariyalur Groups (Turonian and Senonian) of Southern India. But till now these rhynchonellids were not examined critically with a view to studying their phylogeny, as was done by Buckman[9,13] and others[14,15,24,25,26,30,41, etc.,] in the case of other rhynchonellid faunas, the results of which are summarised by Buckman[13] and Thomson.[50] The methods of securing the internal casts, by removing the tests of fossils, for exposing their internal characters such as the muscle marks, and of studying the brachial skeletons in serial sections, both transverse and longitudinal, by grinding down the burnt specimens are fully described by Buckman,[10,11,13] Thomson[50] and Muir-Wood.[33] In the author's opinion, however, serial sections although helpful in a general way are not useful in separating closely allied forms. The absence of restorations of cardinalia or brachial features in spite of multitudinous serial sections figured, for example, by Muir-Wood and others, reduces their intrinsic value. The few serial sections here figured are given to show the general features of the internal characters, and not to indicate their distinctions from closely allied forms.

The rhynchonellids described here were collected by the late Prof. K. K. Mathur and by the present writer from the neighbourhood of Chirakhan (lat. 22° 22′ 30″, long. 75° 7′ 30″), Indore State, Central India, where these beds were first noticed by Col. Keatinge[27] who referred them to the Cretaceous. Though rhynchonellids are reported to occur in both the Deola-Chirakhan Marl and the Coralline Limestones,[6,22,23,40] their relative abundance in these different beds is uncertain; because the Limestones are so hard that the fossils contained in them are available only after weathering

of the rock; and thus they occur mixed up with the fossils from the Marl. The method of burning pieces of the Coralline Limestones, as was done by the Shan Navvy in case of Burma fossils,[13] might enable one to secure fossils from the Coralline Limestones themselves; but the process is not very desirable, because many of the external characters of the fossils are lost, as happened in the case of the Burma Brachiopoda.[13] Owing to this unfavourable nature of the Limestones, a collection of fossils could not be made bed by bed; and though the phylogeny of the present rhynchonellids could be studied, the possible evolutionary stages of their various characters could not be traced successively from one bed to another.

Measurements in Rhynchonellids.

Since dimensions are often useful along with other characters, in separating brachiopod, especially rhynchonellid and terebratulid species, it is essential that such factors should be selected for measurements as are always obtainable, and that no other factors influence them. As beaks are not always preserved in fossil brachiopods, a measurement intended for the base-line would not be satisfactory if it included the beak; again, if the distance from the dorsal umbo to the middle point of the dorsal fold be chosen as the base-line measurement, species like *Burmirhynchia depressa* Buckman,[13] with feebly developed fold, cannot be adequately compared with species like *Rhynchonella acuta*,[13] with much everted fold; because the increased dorsal throw of the fold does not necessarily mean an increase in length. So Buckman[13] chose for the base-line measurement, the distance from the dorsal umbo to the anterior end of lateral commissure, *i.e.*, AA′ in Figs. 1 and 2; all the other measurements which follow are expressed as percentages of the base-line, and are always in the same order as enumerated here. A second measurement, to express the rostration is taken from the beak to the anterior end of the lateral commissure, *i.e.*, A′B in Figs. 1 and 2. AC in Figs. 1 and 2 measured from the dorsal umbo to the furthest point on the fold represents the degree of protrusion of the fold. The fourth and fifth measurements are DD′ in Fig. 3 for breadth and EE′ in Fig. 3 for thickness. Yet another measurement A′C in Figs. 1 and 4 intended to express the extent of the dorsal projection of the fold may be taken in case of much everted folds as in *Rhynchonella acuta*; it is, however, not always necessary nor quite easy to take.

As is evident from Fig. 2 the base-line AA′ and the rostration A′B are measured in a direction of which the obliquity becomes more or less accentuated according to the breadth of the test and of the fold. So in the case of species with broad tests and relatively narrow folds and those with

narrow tests and relatively broad fold, the obliquity of the base-line AA′ being variable in opposite directions, other dimensions which are reduced to

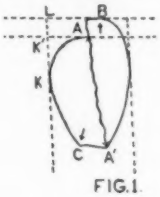


FIG.1.

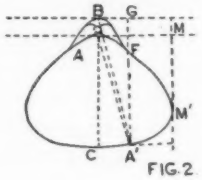


FIG.2.

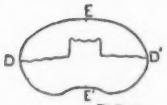


FIG.3.

FIG.4.

its percentages, will be affected in opposite senses and will give fairly approximate values for species which may be quite different from each other. Thus, with such a variable base-line one cannot have a true comparison between different species.

To give a true comparative significance to these measurements, the base-line must be chosen in a direction independent of all variations in the breadth of the test and of the fold. This is done by taking the base-line measurement along a perpendicular between the parallels passing through the dorsal umbo and through the anterior end of lateral commissure, *i.e.*, A′F in Fig. 2. Similarly, the measurement for the degree of rostration should be taken along a perpendicular between the parallels passing through the beak and through the anterior end of the lateral commissure, *i.e.*, A′G in Fig. 2.

While it thus gives a theoretically *true* base-line, the practical advantage gained is that the protrusion (or retraction) of the fold is expressed true to its value (*i.e.*, above, below or equal to 100 as the case may be). The importance of taking measurements in the new way as described above was very keenly felt while working with the cretaceous rhychonellids with which the writer has been busy for some time past. According to the older system of measurement, which the writer followed in the beginning, the percentage value obtained for the protrusion of the fold was less than or equal to 100, unless the fold protruded beyond a certain limit, *i.e.*, unless AC (in Fig. 2) subtended at A′ an angle greater than that subtended by AA′ at the point C. Thus in some individuals with a weakly developed fold, the percentage value of the protrusion would be equal to or less than 100, though the specimen, when viewed in profile, would actually show the

fold to be of a protrusive nature. It must, here, be clearly understood that a fold does not necessarily protrude beyond the anterior end of the lateral commissure, even if the percentage value of the protrusion is more than 100 ; because in such cases the dorsal throw of the fold has, to a certain extent, masked its protrusive nature.

The case is too evident to be explained at any greater length and need only be illustrated by a comparative table giving the values as obtained by the two different methods of measurement. A few species from Namyau Beds of Burma, which are already described by Buckman,[13] are chosen for the purpose.

The base-line chosen for the rhynchonellids is not suitable in the case of the terebratulids, because in the latter group the anterior end of the lateral commissure is not well defined ; so the base-line and rostration are measured from the middle point of the anterior margin to the dorsal umbo and to the beak respectively.[13] It is obvious that the modification here proposed for measurement of the base-line and the rostration is not applicable to terebratulids.

While working with British Chalk terebratulids, Dr. M. R. Sahni[42] found it useful to have a measurement (which might be used with advantage in rhynchonellids also) for the distance of highest point of the dorsal valve from the beak, *i.e.*, KL in Fig. 1 ; but since it includes the effect of a second factor, namely the rostration, which is always represented separately, specimens with low beak and the highest point of the dorsal valve away from its umbo, will give values fairly approximate to those of specimens with high beak and the highest point of the dorsal valve nearer the umbo. Moreover, it is not always that beak is preserved in fossils, especially in rhynchonellids. So, if the distance of the highest point of the dorsal valve is measured from the dorsal umbo, *i.e.*, from K to K′, the effect of the second variable factor of the rostration will be eliminated, and as the dorsal umbo is preserved in most cases this measurement can always be obtained. In the case of the British Chalk Terebratulidæ, however, owing to the comparatively soft nature of the matrix, the beaks were invariably well preserved.

Another similar measurement which may be usefully introduced both in rhynchonellids and terebratulids, is for the point of the greatest width of the test from the dorsal umbo, *i.e.*, MM′ in Fig. 2, along a perpendicular between the parallels passing through these points. Percentage values of these last two measurements may be mentioned after the previous five values.

The use of so many measurements and especially the modification here proposed in the method of taking measurements does not mean an attempt

Comparative Table showing Dimensions Obtained by the Two Different Methods of Measurement.

Species	Buckman's System					Proposed System				
	Base-line in mm.	Length in %	Protrusion in %	Breadth in %	Thickness in %	Base-line in mm.	Length in %	Protrusion in %	Breadth in %	Thickness in %
1. *Burmirhynchia orientalis* (Holotype 1167; figd. III, 1) ..	21	115	107 ?	117	82	20·5	?	111	118	83
2. *B. senilis* (Holotype 11701; figd. IV, 9) ..	16	112 ?	102	90	112	15·9	109	102	96	117
3. *B. subglobosa* (Holotype 11677; figd. V, 5) ..	18	..	110	110	90	17·2 ?	?	112	112	96
4. *B. gutta* (Holotype 11693; figd. IV, 5) ..	17	110 ?	105	103	88	15·8	106	108	109	96
5. *B. subovalis* (Holotype 11691; figd. IV, 3) ..	16·5	107	102	102	82	16·1	109	106	110	92
6. *B. rotunda* (Holotype 11729; figd. VII, 12)	12·5	115	100	118	100	11·6	121	110	?	110
7. *B. transversalis* (Holotype 11730; figd. VI, 7) ..	14·0	110	105	140	80	13·2	108	108	148	87
8. *B. globulus* (Holotype 11697; figd. V, 1) ..	12·5	112	105	105	90	12·2	112	112	111	96
9. *B. nammœnsis* (Holotype 11724; figd. VII, 7) ..	14·0	110	103	130	82	13·9	110	102	130	83
10. *B. longa* (Holotype 11719; figd. VI, 1) ..	19·0	112	105	90	77	17·0	107	117	108	89
11. *B. lenglaungensis* (Holotype 11731; figd. VI, 8) ..	14·5	..	107	137	82	14·4	..	112	137	90
12. *Sphenorhynchia subplicata* (Holotype 11745; figd. V, 7) ..	19·0	115 ?	100	90 ?	75	17·9	..	106	99	81

at separating species merely on the basis of these dimensions. But, that the modification is necessary, is obvious from the references made above to the possible cases where anomalous values would otherwise be obtained. If at all measurements are to be introduced, among characters to be studied in separating brachiopod species, they must certainly be independent of any other factors. What importance should be attached to these measurements is always to be decided in accordance with the nature of the available collection and definite stratigraphic evidence. In any case, full consideration must be given to the possible gradations in form as is always done with other morphological characters. All features cannot always be given the same importance in all the faunas ; because the extent of their variation is different in different stocks. And thus we have more or less perfect gradations in some of the features, which characterise the major groups, while the apparent lack of such gradation in other characters becomes the diagnostic feature for the minor groups. Thus the curvature of the beak, which is of generic value in some of the Jurassic rhynchonellid genera,[13] is found to vary even within species of the rhynchonellid genus *Malvirhynchia* from the Bagh Beds ; while dorsal muscle area is found to be more stable in rhynchonellids from the Bagh Beds than in the genus from Burma, namely *Burmirynchia*.[13] These two instances given above are enough to show how the relative importance of morphological characters varies with the nature of available fauna.

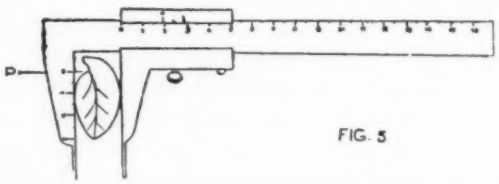


FIG. 5

It is found that the pair of callipers normally available are not suited for these measurements in brachiopods ; because the ends of the jaws are too thick to be accommodated in the narrow space between the beak and the dorsal umbo. But either thin projecting metal strips may be attached, when desired, to the jaws of the usual type of callipers, or a special type of callipers shown in Fig. 5 may be made to order with ends of the jaws thin enough for the purpose. A needle point P passing through the fixed jaw can be pushed down to the desired level so as to hang just over the dorsal umbo ; a scale graduated on the fixed jaw has its zero in line with the needle P and enables one to read the position of highest point of dorsal valve.

Palæontology.

Family RHYNCHONELLIDÆ, Gray, 1848.

Genus MALWIRHYNCHIA,* gen. nov.

Genotype Malwirhynchia transversalis, sp. nov.

(Pl. XXX, Fig. 5 and Text-Figs. 6 and 7.)

Diagnosis.—Multiplicate. Hypothyrid; foramen large, tubular, sub-elliptical to sub-circular. Deltidial plates conjunct. Beak short, sub-erect to almost erect on moderately wide base. Dental plates sub-approximate, moderately divergent. Dorsal umbo planate; dorsal median septum weak reaching up to half the length of the valve; dorsal muscle area pear-shaped extending up to about half the length of the valve, with anterior trigonal adductors well in front of narrow, trigonal, posterior scars, and separated from the latter by straight shallow grooves converging at the median septum. Ventral valve shallower than the dorsal one; ventral muscle area large pear-shaped reaching up to half the length of the valve. Crural bases given off dorsally; crura short, ventrally curved with terminal "Calcarifer".[33] Inner hinge plates joining over the median septum.

General Description.—These rhynchonellids start as a rectimarginate, depressed, biconvex stock with the pre-costate stage unknown; the fine, regular, sub-angular ribs increase by bifurcation. In a few individuals belonging to *Malwirhynchia transversalis* sp. nov., the fine ribbing shows, near the anterior margin, a tendency towards coarseness approaching what is found typically in *M. sub-pentagonalis*, sp. nov.; thus the development of ribbing appears towards increased coarseness. In *M. sub-pentagonalis*, sp. nov., the great rapidity with which the ribs attain the degree of coarseness which is typical of that species, suggests that the costation in these rhynchonellids from the Bagh Beds has very probably developed directly over a smooth shell; and in that case they probably belong to the group of "Læves" of Buckman.[13] The shell is rather rostrate with the ventral valve shallower than the dorsal one; the ventral sinus is more conspicuous and starts much earlier than the dorsal fold which is distinguished from the lateral slopes only towards the anterior margin. The lateral commissures are regular with a slight ventral deflection towards the anterior end. The planareas are shallow, indistinctly demarkated from the ventral surface by rounded beak ridges, and are crossed by three to five fine radial ribs. The pedicle collar is excavated posteriorly at its inner margin. Inclination of the delthyrial plane to the plane of the lateral commissures varies from

* Named after Malwa, the country of origin.

0° to about 45°, but does not appear to be correlated with any of the internal or external characters. In most of the individuals there is a notch at the right or the left end of the mesial fold ; it becomes increasingly conspicuous with the advancing beak ; both the types, the left-hand and the right-hand, are represented in each of the species. The dorsal valve changes its outline from a sub-circular to (1) a transversely elliptical and to (2) a trigonal shape. The general tendency of the shell towards narrowing, with the obesity shifting backwards from the middle of the dorsal valve to about one-thirds of its length from the umbo, a slight average advance in the state of conjunctness of the deltidial plates with a corresponding change in the size and shape of the foramen and a slight expansion of the dorsal muscle area, are observed to proceed concurrently with the advancing beak. All these changes taking place in the direction of their normal course of evolution[13] characterise these rhynchonellids as an anagenetic stock. The wide range of variation in form, a short beak, and the moderately divergent dental plates clearly show that these rhynchonellids were a vigorous and rapidly evolving fauna with no indication of approach to the phylogerontic stage.

Phylogeny.—The post-norella flatness of the dorsal umbo, the precostate stage unknown, but probably a smooth one as suggested above, the shallow ventral valve with its sinus more prominent than the dorsal fold, the moderately divergent dental plates, the hook-like "Calcarifer"[33] terminating the crura and pear-shaped dorsal muscle area point to a very probable origin for *Malwirhynchia* from the Jurassic genus *Kallirhynchia*, Buckman,[12, 13, 32] which is represented by three species in the Jurassic of Cutch.[13, 28] The muscalature of *Malwirhynchia* is a type that would be obtained by the expansion of the muscle area in *Kallirhynchia*. The type of dorsal muscle area and the sub-approximate dental plates also suggest an ancestral trend like that of *Sphenorhynchia*, Buckman.[13] This incidentally tends to support Buckman's observation that *Kallirhynchia* possibly has, like *Sphenorhynchia* Buckman, its origin in a noreliform stock.[13]

The muscalature in *Burmirhynchia*, Buckman[12, 13, 50] shows some resemblance to that of *Malwirhynchia* ; but the widely divergent dental plates, drawn out beak, convex dorsal umbo, curving grooves separating the pairs of dorsal adductor scars and incomplete foramen in the former genus separate it from the latter ; moreover, *Burmirhynchia* shows phylogerontic features such as strong, widely divergent dental plates and produced beak. In *Somalirhynchia*, Weir[34, 51, 52] and *Daghanirhynchia*, Muir-Wood[34] belonging to the *Burmirhynchia-Rhactorhynchia* stock the muscalature has evolved into a type quite different from what is found in *Malwirhynchia*. In *Bihendulirhynchia*, Muir-Wood[34] the brachial valve is posteriorly smooth norelliform ;

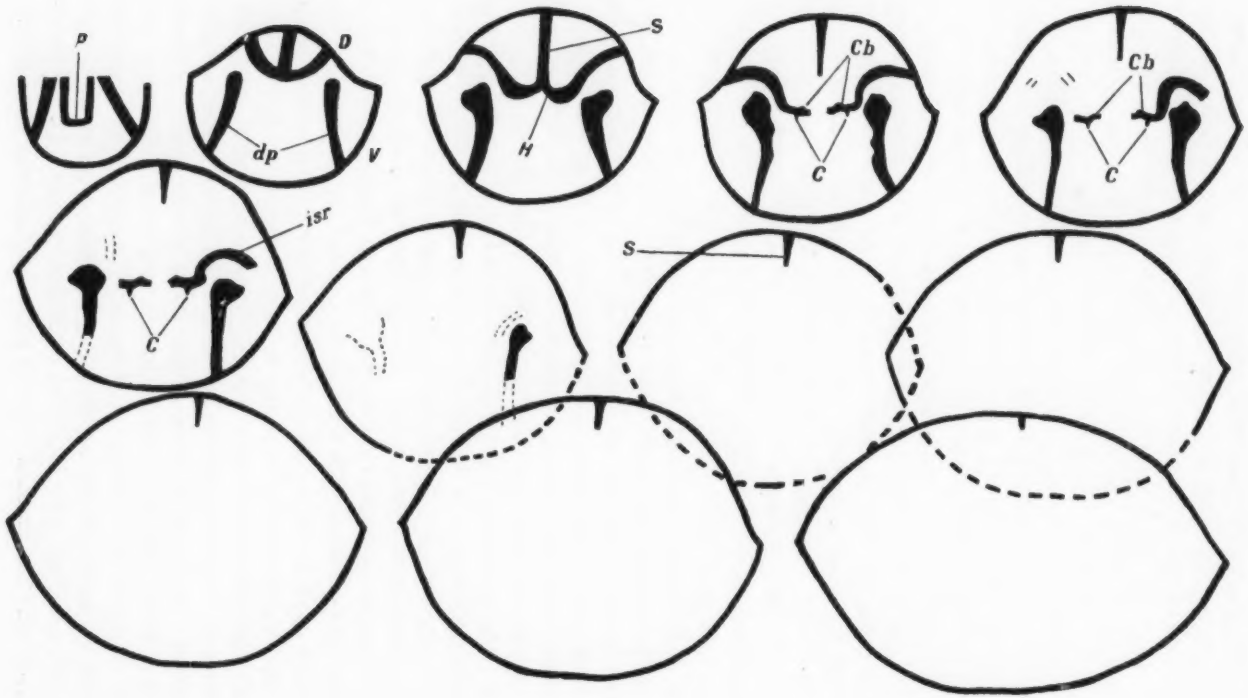


FIG. 6.

Twelve serial transverse sections across the umbo of *Malwirhynchia transversalis*, sp. nov. with dorsal valve above. Sections 1 and 2 at 1 mm. interval beginning from the posterior end of the shell; Sections 3 to 11 at 0·3 mm. to 0·2 mm. interval; Section 12 after 1·2 mm. interval; *D*–dorsal valve; *V*–ventral valve; *S*–median septum; *dp*–dental plates; *isr*–inner socket ridge; *H*–inner hinge plates; *Cb*–crural bases; *C*–crura; *P*–pedicle collar. All sections × 6.

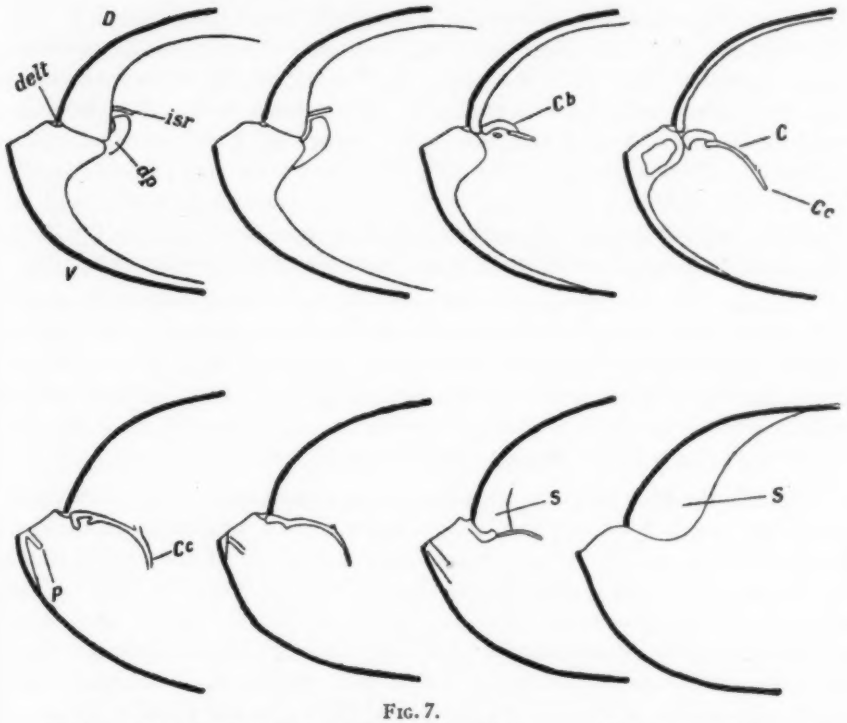


FIG. 7.

Eight serial longitudinal sections of *Malwirhynchia transversalis*, sp. nov. taken postero-anteriorly to show the crura and median septum with dorsal valve above. Section 1 taken at 4 mm. distance from the point of greatest width ; Sections 2 and 3 at 0·3 mm. interval ; Sections 4 to 8 at 0·2 mm. interval. *D*–dorsal valve ; *V*–ventral valve ; *S*–median septum ; *dp*–dental plates ; *isr*–inner socket ridge ; *Cr*–Crural base ; *C*–Crura ; *Cc*–Calcarifer ; *P*–pedicle collar ; *delt*–deltidial plates. All sections × 6.

the ventral valve is shallow and the dorsal muscle area trigoniform resembling that in *Malwirhynchia* ; but the adductor scars are situated far away from the short median septum ; while the pedicle collar is supported by a septum. *Kutchirhynchia* Buckman[12, 13] with an incurving beak, the mesial fold more conspicuous than the ventral sinus, long dental plates and half-moon shaped dorsal anterior scars, has evolved from the *Kallirhynchia* stock along a branch obviously different from the one which led to *Malwirhynchia*.

Cyclothyris McCoy[8, 13, 30, 31, 43] with its dorsal muscle area anteriorly much expanded, dental plates long, hinge plates divided and dorsal septum incipient to obsolete, is easily distinguished from *Malwirhynchia*. *Septaliphoria* Leidhold[30] has a septalium, an incomplete foramen (complete in old age) and a dorsal muscle area with anterior scars oval and posterior scars

circular. *Rhynchonella plicatiloides* Stoliczka[47] from the Turonian and Senonian of South India, to which Bose[6] had referred a part of the rhynchonellids from the Bagh Beds, is a much bigger race ; its ribs are more rounded and the ventral umbo is much shallower, with a lower beak. A preliminary examination of the rhynchonellids from South India shows that their internal characters are probably different from those of *Malwirhynchia*. *Rhynchonella depressa*, Sow[4, 7, 18, 19, 32, 44, 46, 48] from the Upper Green Sand of England to which Duncan[22, 23] had referred these rhynchonellids from the Bagh Beds, has its beak ridges very sharp and plan areas are devoid of radial ribs.

Among the post-Cretaceous rhynchonellids, *Tegulorhynchia*, Chapman and Crespin,[15, 26, 50] a possible derivative of the *Burmirhynchia* stock, clearly differs from *Malwirhynchia*, by its septum not united with the cardinalia, the ventrally recessive dental plates, etc. *Hemithyris* d'Orb.[17, 20, 25, 36, 49, 50] with a smooth to finely multicostate shell, has an incomplete foramen, no inner hinge plates and a quadrate dorsal muscle area.

Due to the wide range in variation in the dimensions and other external characters, a select collection of 480 specimens† could reasonably be divided into only three species in accordance with the nature of the shell-outline. To compare the three species among themselves, *Malwirhynchia transversalis* is the most variable group ; its moderately developed mesial fold, and a sub-elliptical to sub-circular foramen show that it is more advanced than *M. trigonalis* in which the mesial fold is less conspicuous. As mentioned above, the coarse ribbing of *M. sub-pentagonalis* appears to be a development of the finer ribbing which characterises the other two species ; also its well-developed mesial fold, sub-circular foramen and tetragonal deltidial plates show that it is the most advanced species among the Bagh rhynchonellids.

Description of the Species.

Malwirhynchia sub-pentogonalis, sp. nov.

(Pl. XXX, Figs. 1 to 4.)

Dimensions.— 10·9, 114, 110, 119, 73.
10·4, 111, 115, 130, 77.
10·4, 110, 124, 127, 82.
11·0, 107, 107, 120, 66.
9·2, 112, 114, 127, 66.

N.B.—All the type specimens are preserved in the Department of Geology, Benares Hindu University.

† From a collection of over a thousand specimens, only such specimens as were well preserved were selected for the present work.

Description.—Shell sub-pentagonal, sub-medianly widest and thickest, moderately tumid, rather coarsely ribbed with 30 to 35 ribs on the dorsal valve, and 8 to 11 ribs on the protrusive, planoplicate[39] mesial fold ; commissures rather sharp ; ventral umbo strong with a sub-erect beak ; foramen hypothyrid tubular, large, sub-circular ; deltidial plates high, conjunct, tetragonal.

Comparison.—For distinction from *M. transversalis*, sp. nov. see below. Stronger and fewer ribs, sub-pentagonal shell with sharp margins, strong ventral umbo and protrusive fold distinguish this form from *M. trigonalis*, sp. nov. described below.

Remarks.—An approach to coarseness and relative sub-angularity of the ribbing of this form is only just indicated in some individuals of *M. transversalis*, sp. nov. near the anterior margin, but the character is not pronounced.

Material.—Number of specimens studied 32.

Malwirhynchia transversalis, sp. nov.

(Pl. XXX, Figs. 5–12 and Text-Figs. 6–7.)

Dimensions.— 10·2, 113, 116, 138, 68.
10·7, 107, 105, 139, 78.
9·4, 115, 106, 135, 80.
11·0, 107, 107, 127, 58.
11·7, 109, 106, 119, 74.
10·7, 112, 101, 110, 64.
10·0, 115, 112, 149, 75.
10·2, 115, 110, 122, 75.

Description.—Shell depressed to moderately obese ; dorsal valve sub-circular to transversely elliptical, medianly widest, highest between the middle and one-third length from the umbo ; mesial fold moderately developed, plano-plicate to obtusi-plicate,[39] becoming distinct from the lateral slopes only towards the anterior margin ; commissures not sharp ; surface with 40 to 50 sub-angular ribs ; 10 to 15 ribs on the mesial fold ; beak sub-erect to almost erect ; foramen hypothyrid, tubular, moderately large, sub-elliptical ; deltidial plates high, trigonal to incipiently tetragonal, conjunct.

Comparison.—Finer and more angular ribbing, sub-circular to transversely elliptical outline, weaker ventral umbo, dorsal fold less protrusive but more raised, and less acute anterior commissure distinguish this species from *M. sub-pentagonalis*, sp. nov. described above. From *M. trigonalis*, sp. nov. described below, the present species differs by its sub-circular to transversely elliptical outline, greater variability, of the shell contour,

mesial fold more protrusive and more generally distinct from the lateral slopes towards the anterior margin.

Remarks.—This species is chosen as the genotype as it typically shows the wide range of variation in the various features which are characteristic of the genus; it is also the most abundant of the representatives of this genus.

Material.—Number of specimens studied 362.

Malwirhynchia trigonalis, sp. nov.

(Pl. XXX, Figs. 13–20.)

Dimensions.— 10·6, 113, 109, 124, 68.
9·6, 106, 106, 125, 69.
9·9, 111, 105, 118, 71.
11·6, 109, 114, 139, 83.
9·2, 109, 110, 128, 77.
10·2, 106, 107, 125, 78.

Description.—Shell depressed to tumid, trigonal, anteriorly widest and sub-medianly highest, with blunt commissures; surface with 40 to 50 fine sub-angular ribs; mesial fold obtusi-plicate or plano-plicate,[39] hardly protrusive, generally not distinct from the lateral slopes; ventral umbo moderately strong with sub-erect to nearly erect beak; foramen hypothyrid, tubular, moderately sized, sub-elliptical to sub-circular; deltidial plates trigonal, high, conjunct.

Comparison.—For distinction from other forms see above.

Material.—Number of specimens studied 86.

Geological Age.

In the absence of any Cretaceous rhynchonellid fauna studied along the lines followed in the present work and of which the geological horizon is fixed accurately, it is very difficult to arrive at a definite conclusion as regards the age of these rhynchonellids from the Bagh Beds. However, by a comparative study of the external characters of the Bagh rhynchonellids and of those from other parts of the world, where their stratigraphical position is already fixed on the basis of other fossils, a probable age for the rhynchonellids from the Bagh Beds may be suggested.

Rhynchonella deluci, Pictet[1, 38] from the Lower Gault of the Alps and Upper Cretaceous of Caucasus comes very close to *Malwirhynchia trigonalis*, sp. nov. by its fine, regular ribbing, the ventral valve shallower than the dorsal one, the shallow planareas with fine radial ribs, the pre-costate stage unknown and the slight asymmetry of the shell; but its beak is a little more advanced

than that of the Bagh species. In the forms such as *Rhynchonella plicatilis* Sow. *Rhynchonella grasiana* J'Orb., *Rhynchonella depressa*, Sow. and *Rhynchonella nuciformis* Sow. all from the Upper Green Sand, [1,2,4,7,18,19,32,35,38,44,46,48] the beak is more advanced than that of the rhynchonellids from the Bagh Beds; but they all have their mesial fold at about the same stage of development as attained in the Bagh fossils. *Rhynchonella plicatiloids* Stol. from the Turonian and Senonian of South India,[47] and the Senonian of Persia,[13] and Japan,[53] has its beak and the mesial fold more advanced than those of the species of *Malwirhynchia*.

So far as can be judged from the above comparative study of the morphological characters of the different rhynchonellid species, the age of the Bagh fossils appears to range between the Lower Gault and Senonian—and very probably from the Gault to the Cenomanian. Thus the results of the present study of the rhynchonellids from the Bagh Beds, appear to corroborate, though roughly, the conclusions already arrived at from the study of the echinoids from these beds.[16]

Acknowledgments.

In conclusion, I have to acknowledge my great indebtedness to the late Prof. K. K. Mathur for kindly putting at my disposal his collection of the Bagh fossils, which forms a part of the material for the present work. Very sincere thanks are due to Dr. Raj Nath and to Dr. M. R. Sahni for kindly going through the manuscript of this paper and for valuable criticism. I also take this opportunity of thanking the Director, the Geological Survey of India, for permission to work in their Survey museum and library.

The author is very much indebted to the Indore Durbar for the kind permission to collect fossils from their territory and for the facilities given during the field work.

BIBLIOGRAPHY.

1. Anthula, D. J. .. "Uber die wreidefossilien des Kaukesus mit einem allgemeinen Ueberlick über die Sedimentärbildungen des Kaukesus," *Beitr. Pal. Geol. Österreich-Ungarns und des Orients*, 1899, **12**, Heft. 2.

2. d'Archiac .. "Observations sur les group moyen de la formations Crétacé," *Mém. Soc. Géol. France*, 1839, **3**, No. 8.

3. Arthaber, G., von .. "Uber das Paläozoicum in Hocharmenien and Persien mit einem Anhang über die Kreide von Sirab in Persien," *Beit. Pal. Geol. Österreich-Ungarns und des Orients*, 1900, **12**, Heft. 4.

4. Austen, R. A. C. .. "On the age and position of the fossiliferous sands and gravels of Farringdon," *Proc. Geol. Soc., Q.J.G.S.*, 1850, **6**, 454–78.

5. Blanford, W. T. .. "On the Geology of the Taptee and Narbada valleys and some adjoining districts," *Mem. G.S.I.*, 1869, **6**, Pt. 3.

6. Bose, P. N. .. "Geology of the lower Narbada valley between Nimawar and Kawant," *Mem. G.S.I.*, 1884, **21**, Pt. 1.

7. Buch, Leopald, von .. "Essai d'Une classification et d'une description des Térébratules," *Mem. Soc. Geol. France*, 1838–39, **3**, No. 6.

8. Buckman, S. S. .. "Brachiopod Nomenclature," *Ann. Mag. Nat. Hist.*, 1906, (7), **18.**

9. ———— .. "Certain Jurassic (Inferior Oolite) species of Ammonites and Brachiopoda," *Q.J.G.S.*, 1910, **66**, 90–110.

10. ———— .. "A method of removing tests from fossils," *Amer. Jour. Sci.*, 1911, (2), **32**, 163.

11. ———— .. "A method of removing tests from fossils," *ibid.*, 1912, (2), **33**, 593.

12. ———— .. "Brachiopoda of the Namyan Beds of Burma," *Rec. G.S.I.*, 1915, **44**, Pt. 1, 75–81.

13. ———— .. "Brachiopoda of the Namyan Beds, Northern Shan States, Burma," *Pal. Ind.*, 1917, N. S. **3**, mem. No. 2.

14. ——, and Walker .. "On the spinose rhynchonellæ (Genus *Acanthothyris* d'Obrb.) found in England," *Report for 1888 Yorkshire Phil. Soc.*, 1889, 41–57.

15. Chapman, F., and Crespin, I. (Miss) "The Austral Rhynchonellecea of the 'Nigricans Series' with a special description of the new genus *Tegulorhynchia*," *Proc. Roy. Soc. Vict.*, 1923, N.S., **35**, 175–80.

16. Chiplonker, G. W. .. "Echinoids from the Bagh Beds," *Proc. Ind. Acad. Sci.*, 1937, **6**, No. 1, 60–77.

17. Dall, W. H. .. "Annotated list of the recent Brachiopoda in the collection of the United States National Museum, with description of thirty-two new species," *Proc. U.S. Nat. Museum*, 1920, **57**.

18. Davidson, T. .. "Monograph of the British Fossil Brachiopoda—the Cretaceous Brachiopoda," *Monogr. Pal. Soc.*, 1852–55, **1**, Pt. 2.

19. ———— .. "Monograph of the British Fossil Brachiopoda," *Supplement, ibid.*, 1874, **4**, Pt. 1.

20. ———— .. "Monograph of recent Brachiopoda," *Trans. Linn. Soc., London (Zool.)*, 1887, (2), **4**, Pt. **2**, 163–68.

21. ——, and Morris, J. .. "Description of some species of Brachiopoda," *Ann. Mag. Nat. Hist.*, 1847, (1), **20**.

22. Duncan, Martin, P. .. "Description of the Echinodermata from the Strata on the South-Eastern Coast of Arabia and at Bagh on the Narbada in the collection of the Geological Soceity," *Q.J.G.S.*, 1865, **21**.

23. ———— .. "Notes on Echinoidea of the Cretaceous Series of the Lower Narbada Valley with remarks upon their Geological Age," *Rec. G.S.I.*, 1887, **20**, Pt. 2.

24. Hall, J., and Clarke, J. M. .. *Palæontology of New York*, 1893, **8**, Pt. 2.
25. ———— .. "Introduction to Study of Brachiopoda," *Report of the Geological Survey of the State of New York*, 1894.
26. Hutton, F. W. .. "Revision of the Tertiary Brachiopoda of New Zealand," *Trans. N.Z. Inst.*, 1905, **37**.
27. Keatinge, Col. .. "Neocomian fossils from Bagh and its neighbourhood," *Jour. Bom. As. Soc.*, 1857, **5**, 621–24.
28. Kitchin, F. L. .. "Jurassic Fauna of Cutch—The Brachiopoda," *Pal. Ind.*, 1900, (9), **3**, Pt. 1.
29. Lamplugh, G. W., and Walker, J. F. .. "On a fossiliferous band at the top of the Lower Green Sand near Leighton Buzzard, Bredfordshire," *Q.J.G.S.*, 1903, **59**.
30. Leidhold .. "Beitrage zur genaueren kenntnis und systematik einiger Rhynchonelliden des reichländischen Jura," *N. Jahrb. Min.*, 1920, **44**, 343–68.
31. McCoy .. *Carboniferous Fossils from Ireland*, 1844.
32. Morris, J. .. *A Catalogue of British Fossils*, London, 1854.
33. Muir-Wood, H. M. .. "The internal structures of some Mesozoic Brachiopoda," *Phil. Trans. Roy. Soc. London*, 1934, **223**, 511–67.
34. ———— .. "The Mesozoic Palæontology of British Somaliland, The Jurassic Brachiopoda," 1935, 75–147.
35. Nielsen, K. B. .. "Brachiopoderne i Denmarks Kridtaflejringer," *Mém. Acad. Roy. Copenhagen*, 1909, (6), **7**, Pt. **4**.
36. d'Orbigny, A. "*Paleontologie Francaise—Terr. Crét. Brachiopodes*," 1847, **4**.
37. ———— .. "*Prodrome de Paléontologie Stratigraphique universelle des animonx mollusques et rayonées*," 1850, **2**, Paris.
38. Pictet, F. .. "Description du Terrain Crétacé des environs de Sainte-Croix," *Matér. Pal. Suisse.*, 1872, **6**, Pt. 5.
39. Raj Nath .. "Terminology of some types of Folding in Brachiopodes," *Quart. J. Geol. Min. & Met. Soc. India*, 1932, **3**, No. 4, 189–93.
40. Rode, K. P., and Chiplonker, G. W. .. "A Contribution to the Stratigraphy of the Bagh Beds," *Curr. Sci.*, 1935, **4**, 322.
41. Rothpletz, A. .. "Geologisch-palæontologische Monographie der Vilser Alpen, mit besonderer Berüchsichtigung der Brachiopoden systematik," *Palæontographica*, 1886, **33**.
42. Sahni, M. R. .. "Morphology and Zonal Distribution of some Chalk Terebratulids," *Ann. Mag. Nat. Hist.*, 1925, (9), **15**.
43. Schuchert, C. .. "Brachiopoda" in *Text-Book of Palæontology*, by C. Von Zittel, edited by C. E. Eastman, 2nd Ed. revised, 1927.
44. Sharpe, D. .. "On the age of fossiliferous sands and gravels of Farringdon and its neighbourhood," *Proc. Geol. Soc., Q.J.G.S.*, 1853, **10**, 176–98.
45. Sowerby, J. .. *Mineral Conchology of Great Britain*, 1816, **2**.
46. ———— .. *Ibid.*, 1825, **5**.
47. Stoliczka, F. .. "Cretaceous Fauna of Southern India Brachiopoda," *Pal. Ind.*, 1872, (8), **4**, Pt. 1.

48. Tennant, J. .. *A Stratigraphic List of British Fossils*, 1847, London.
49. Thomson J. Allan .. "Genera of Recent and Tertiary Rhynchonellids," *Geo. Mag.*, 1915, dec. 6, **2**.
50. ———— .. "*Brachiopod Morphology and Genera (Tertiary and Recent)*," 1927, New Zealand Board of Science and Art, Manual No. 7, Wellington, N. Z.
51. Weir, J. .. "Brachiopoda, Lamellibranchiata, Gastropoda and Belemnites" in *On the Collections of Fossils and Rocks from Somaliland* made by Messrs. B. K. N. Wyllie and W. R. Smellie," *Monogr. Geol. Dept. Hunterian Mus. Glasgow Univ.*, 1925, **1**, Pt. **4**.
52. ———— .. "Jurassic fossils from Jubaland, East Africa, collected by V. G. Glenday," *ibid.*, 1929, **3**, 1–63.
53. Yabe, H. .. "Cretaceous Stratigraphy of the Japanese Islands," *Sci. Reports Tohoku Imp. Univ. Sendai, Japan*, 1927, (2), (Geology), **11**, No. 1.

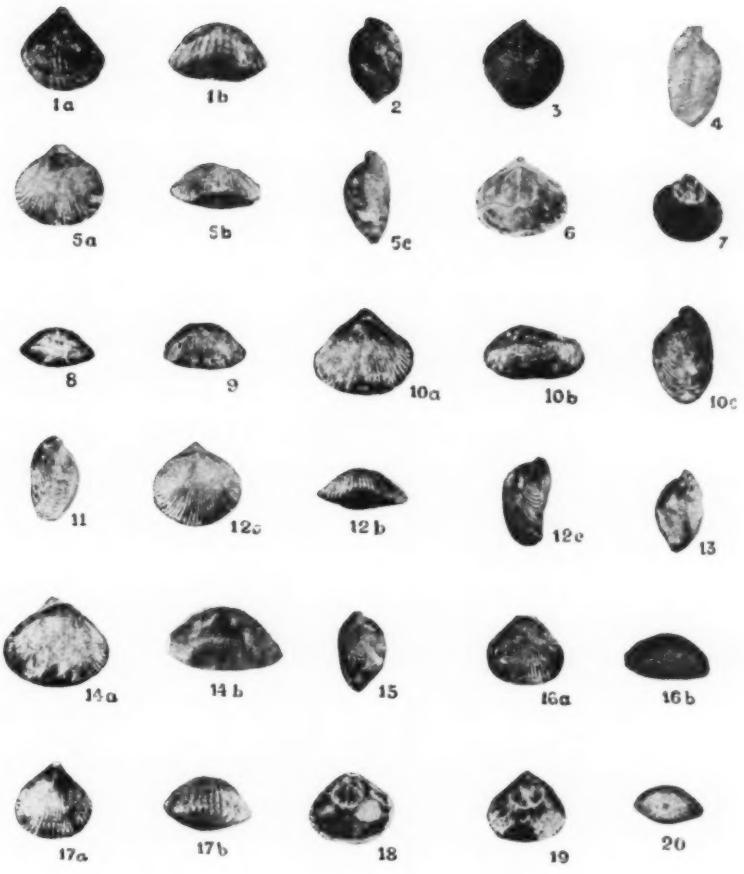
EXPLANATION OF PLATE XXX.

FIGS. 1–4.—*Malwirhynchia sub-pentagonalis*, sp. nov.—fig. 1*a*, dorsal view, external; fig. 1*b*, anterior view (Holotype; B.H.U. No. B/1); fig. 2, lateral view (Paratype; B.H.U. No. B/1-1); fig. 3, cast showing dorsal muscle area (Paratype; B.H.U. No. B/1-2); fig. 4, lateral view (Paratype; B.H.U. No. B/1-3).

FIGS. 5–12.—*M. transversalis*, sp. nov.—fig. 5*a*, dorsal view, external; fig. 5*b*, anterior view; fig. 5*c*, lateral view (Holotype; B.H.U. No. B/2); fig. 6, cast showing dorsal muscle area (Paratype; B.H.U. No. B/2-1); fig. 7, cast showing ventral muscle area (Paratype; B.H.U. No. B/2-2); fig. 8, umbonal view of a cast showing dental plates (Paratype; B.H.U. No. B/2-3); fig. 9, anterior view (Paratype; B.H.U. No. B/2-4); fig. 10*a*, dorsal view, external; fig. 10*b*, anterior view; fig. 10*c*, lateral view (Paratype; B.H.U. No. B/2-6); fig. 11, lateral view (Paratype; B.H.U. No. B/2-5); fig. 12*a*, dorsal view, external; fig. 12*b*, anterior view; fig. 12*c*, lateral view (Paratype; B.H.U. No. B/2-7).

FIGS. 13–20.—*M. trigonalis* sp. nov.—fig. 13, lateral view (Paratype; B.H.U. No. B/3-3); fig. 14*a*, dorsal view, external; fig. 14*b*, anterior view (Holotype; B.H.U. No. B/3); fig. 15, lateral view (Paratype; B.H.U. No. B/3-4); fig. 16*a*, dorsal view, external; fig. 16*b*, anterior view (Paratype; B.H.U. No. B/3-1); fig. 17*a*, dorsal view, external; fig. 17*b*, anterior view (Paratype; B.H.U. No. B/3-2); fig. 18, cast showing dorsal muscle area (Paratype; B.H.U. No. B/3-5); fig. 19, cast showing ventral muscle area (Paratype; B.H.U. No. B/3-6); fig. 20, umbonal view of cast showing dental plates (Paratype; B.H.U. No. B/3-7).

N.B.—All figures are of natural size.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ON CERTAIN DOUBLE MONSTROSITIES OF GAMBUSIA.

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Received October 22, 1937.
(Communicated by Prof. C. R. Narayan Rao, M.A.)

The occurrence in the animal kingdom of double monstrosities is a well-known phenomenon, and several examples have been described from practically every group amongst the vertebrates. Almost all the abnormal fishes thus far described, have been obtained from fish hatcheries—from the oviparous types. The material now to be described was obtained from a viviparous fish—a Gambusia. On account of the rarity of the occurrence of double monstrosities in viviparous fish, it has been considered worth while to offer a brief description.

General Description of the Specimens.

Specimen 1.—This was alive when born and continued to live for more than four hours after birth. The body was clearly double except at the extreme anterior end (Fig. 1, *a* and *b*). The two components (*X* and *Y*) of

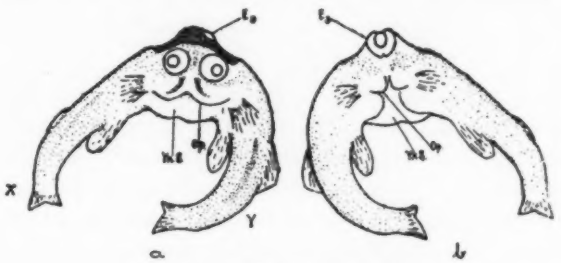

Fig. 1. Drawing of specimen.

the monster were almost equal in size. The specimen when first noticed was moving round and round in a horizontal plane. The heart could be seen beating vigorously. At the end of four hours the cardiac and the respiratory activities were noticed to slow down considerably. At this stage the specimen was transferred into Bouin's fixing fluid. On further examination of the entire specimen the following points were made out. The mouth slits were not to be seen. On one side of the specimen (Fig. 1, *a*) two eyes

could be made out—the right eye of component *X* and the left eye of component *Y*. On the other side of the specimen (Fig. 1, *b*, *E 3*) could be seen, one large eye, clearly showing traces of its double origin—the result of the fusion of the left eye of component *X* and the right eye of component *Y*. Two opercular slits (*Op.*) were to be noticed on either side of the specimen, but

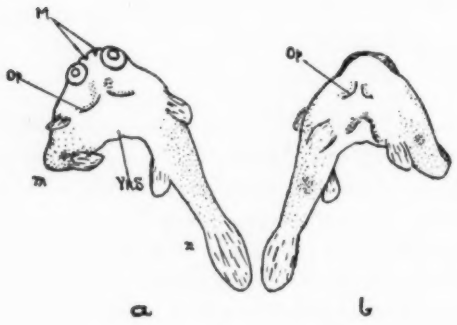

FIG. 2. Drawing of specimen.

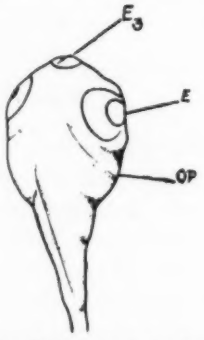

FIG. 3. Drawing of specimen. Lettering : *E*–Normal eye ; E_3–the fused third eye ; *Op*–Opercular slits ; *Yk.S.*–yolk sac.

those on the side bearing the two normal eyes were bigger than the slits on the other side. The heart, as could be seen in the living specimen, was situated on the side which bore the normal eyes. The pectoral fins of both the components were equally well developed, and did not show any peculiarities. The pelvic fins were not to be seen.

Specimen 2.—This was born dead. One of the components (Fig. 2) *M* was smaller than the other—*N*. In this as in the previous specimen fusion had occurred only at the extreme anterior end, while the rest of the body was double. Two mouth slits could be noticed at the anterior end. On one side of the specimen (Fig. 2, *a*) two normal eyes could be noticed, while on the other side (Fig. 2, *b*) no eye-like structure could be seen. The opercular slits on the side bearing the eyes were larger than those on the other side. All four gill slits were very poorly developed. The fins were all equally well developed. As in the previous specimen the pelvic fins were absent.

Specimen 3.—This was also born dead. The body was single throughout (Fig. 3). The specimen as could be seen from the sections was in an advanced state of decomposition. The fins were all absent. There was no mouth, but in the position usually occupied by it, there was a black mass which on gross examination looked like a cyclopic eye. Except for this no abnormality could be observed in this specimen.

These two specimens were also passed into Bouin's fixative. Paraffin sections were cut 8μ thick and the sections were stained in Delafield's hæmatoxylin, counterstained with picro-indigo-carmine.

Detailed Description.

Specimen 1.—A section passing through the anterior portion of the specimen is depicted in Fig. 4. The two normal eyes (*E*) as well as the fused

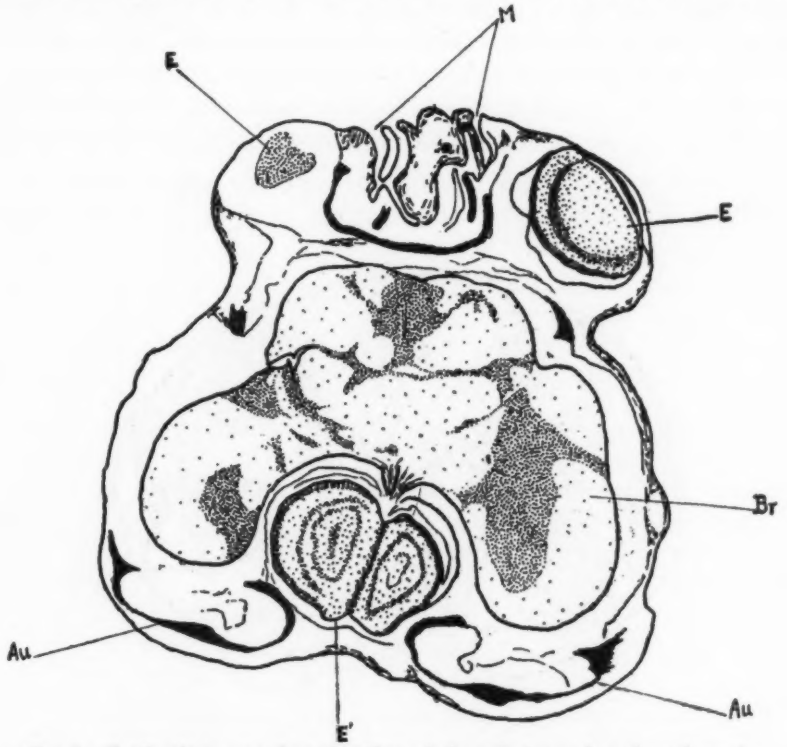

FIG. 4. Section (transverse) passing through the anterior region of specimen A. *Au*-Auditory capsule; *Br*-Brain; *E*-Normal eyes; *E'*-the fused eye; *M*-the mouth slits.

third eye (E') are seen in section. This fused eye possesses a double retinal cup and its nerve supply is also double—the two halves of the retinal cup receiving nerves from the brain masses of the corresponding sides. The brain masses of the two components of the specimen are noticed to have fused up to this region—the mid-brain region. Two of the auditory vesicles (*Au*) of the specimen are to be seen in this section. The specimen is provided with four ear vesicles as can be seen from later sections. Though the mouth

slits were not visible to the gross inspection, they are now quite evident in this section (*M*). Later sections reveal that the fused eye possesses a single lens. The two normal eyes obtain their nerve supply from the brain masses of the opposite sides—the left eye of component *b* getting its nerve from the brain mass of component *a*, and *vice versa*. The body beyond the midbrain region is entirely double. Corresponding to the four gill slits that are visible to the outside, there are four sets of gills, all equally well developed. The heart shows some traces of double formation. There are two auricles and two ventricles—one of these latter being smaller than the other. There is a single ventral aorta, which has at its base four valves instead of the normal two.

Specimen 2.—Fig. 5 is a camera lucida tracing of a section near the anterior end of the specimen. The two brain masses are distinct and

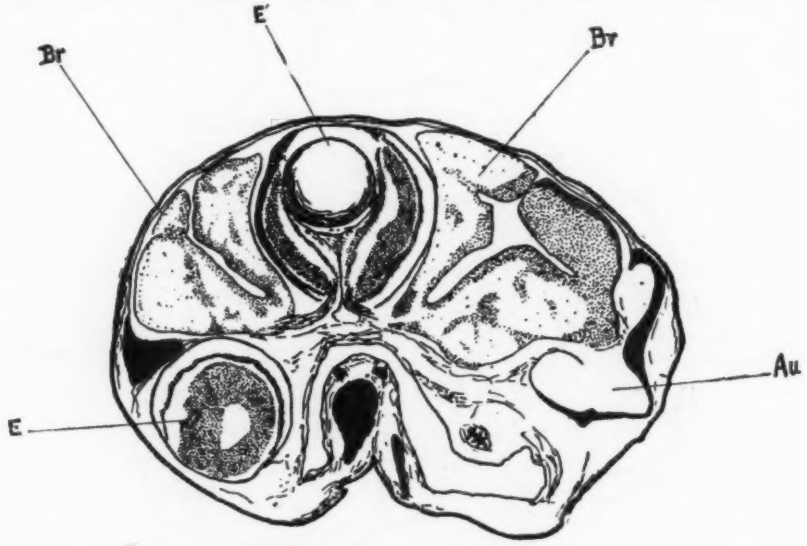

FIG. 5. Transverse section near the anterior region of specimen B.

separate from each other. In this specimen, as can be seen by a study of the sections, the brain masses are separate throughout. One of the normal eyes (*E*) is seen in section. On the other side of the specimen where no eye could be seen to the outside, we find a well developed eye (*E'*) formed by the fusion of the left eye of component *m* and the right eye of component *n*. This structure is situated so deep beneath the skin that it is not visible to the outside. Though this eye (*E'*) possesses a single lens and a single retinal cup, it shows its double origin in its nerve supply, getting two nerves from the brain masses of each of the components. Later sections show that in each

of the components there is the usual crossing-over of the nerve fibres, a feature not noticed in Specimen 1. The two normal eyes get their nerves from the brain masses of the corresponding components.

Further study reveals the fact that this specimen also possesses four auditory vesicles (*Au*) and four sets of gills of which those on the side bearing the normal eyes are bigger. The heart shows some abnormalities in possessing two auricles and a single ventricle.

Beyond the pharyngeal region the body formation is entirely double.

Specimen 3.—This specimen was sectioned in the facial plane. As already stated the material was in a high state of decomposition, yet enough could be made out to state that this was also a monster.

A section passing through both the eyes is shown in Fig. 6. At the anterior end of the specimen where the mouth would naturally have been,

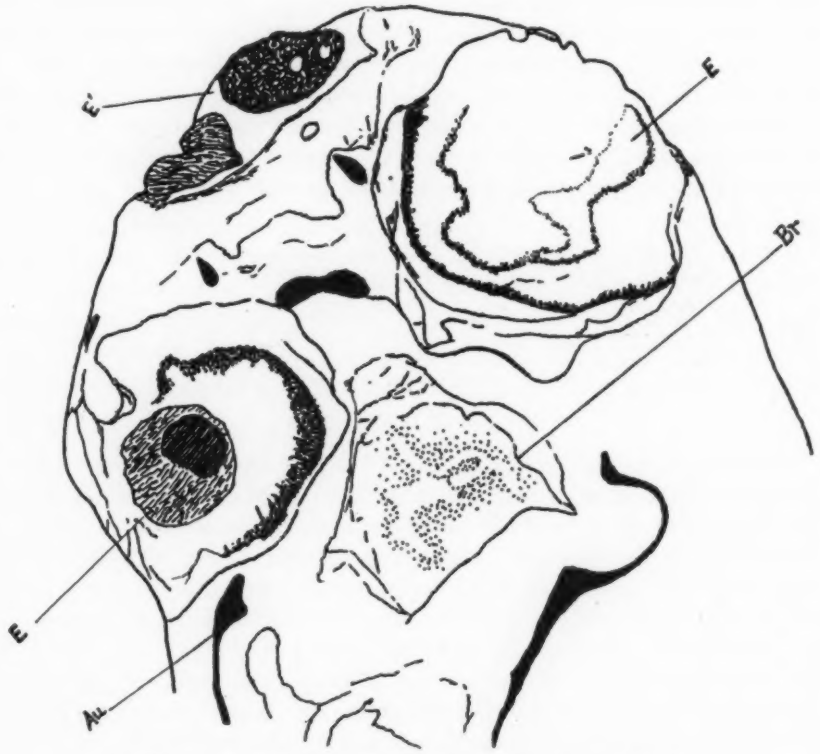

FIG. 6. Facial section of specimen 3. Letterings as before.

we notice a mass of black tissue (*E'*) which resembles very much the tissue found in the position of the normal eye (*E*). Two ear (*Au*) vesicles only are to be noticed in this specimen.

Further study shows that to the left of the brain mass (*Br*) of the specimen, lies some tissue which looks very much like the main mass of the brain. This fact together with the occurrence of the eye-like structure at the anterior end of the specimen, would lead one to infer that here too we have a case of double formation, with one of the components represented by its extreme anterior end only.

Remarks.

The material above described form " double monstrosities ", of which specimens 1 and 2 belong to the *autosite* type of Newmann, while specimen 3 belongs to the *parasite* of the same author. Considering, however, the more detailed classification of Gemmill, these belong to the *anakatadidymous* type, where two embryonal axes are developed on a single blastoderm and the fusion is by the yolk sac only. Gemmill quotes a case of double formation in another vivaparous fish—*Girardinus caudimaculatus*. But in Gambusia, the specimen under co sideration, the type of viviparity is very peculiar. Here we have a case of intraovarian gestation. Hence on account of the development in a confined space, the two embryonic axes seem to have come together by their head ends and fused to some extent.

LITERATURE.

Gemmill, J. F.	..	*Teratology of Fishes.*
Newmann ..	..	*Physiology of Twins.*
———— ..	..	*Biology of Twins.*
Bland Sutton ..	..	*Evolution and Disease.*
Wilson, E. B. ..	..	*Cell in Development and Inheritance.*

ON A NEW NEMATODE PARASITE OF THE HIMALAYAN FLYING SQUIRREL (*PTEROMYS INORNATUS* GEOFFROY).

By M. Abdussalam.

Demonstrator, Punjab Veterinary College, Lahore.

Received April 25, 1938.

(Communicated by Dr. B. L. Bhatia, D.Sc., F.Z.S.)

Large numbers of a small Oxyurid parasite were found in the cæcum of a flying squirrel shot down, at Mukteswar, Kumaon Hills, in the Western Himalayas. These, on examination, proved to be a new species of the genus *Wellcomia* Sambon, 1907.

Sambon (1907), who created this genus, briefly described an Oxyurid parasite of the Cape jumping hare (*Pedets cafer*) under the name *Wellcomia mitchelli*. Baylis (1922) added another species, *W. samboni* parasitic in the hairy porcupine and included in this genus, *Oxyuris evoluta* v. Linstow, 1899, which had been re-described by Smith (1908) under the name *Oxyuris evaginata* and also by Hall (1916). Travassos (1923) added to this genus another species, *W. decorata*, parasitic in *Cændu brandti*. Yorke and Maplestone (1926) redefined the genus and also included in it, *Oxyuris hilgerti* Seurat, 1914, parasitic in *Ctenodactylus gundi* of Algeria. Price (1930) considers that *Oxyuris compar* Leidy which was recorded from the small intestine of a cat in the United States, is also referable to the genus *Wellcomia*. Baylis and Daubney (1922) doubtfully referred to *Oxyuris compar*, a single specimen obtained from a cat at Calcutta ; but Baylis (1936) on re-examination of the worm found that it was a female of some species of *Heterakis*.

Wellcomia taylori sp. nov.

The male is very slender, 1·56–1·74 mm. long and 0·085–0·1 mm. broad ; its posterior extremity is rolled in the form of a spiral so as to give it the shape of a 'sign of interrogation'. The cuticle is finely striated transversely at intervals of 0·008 mm. There are no cuticular ' mammelons ' as in *Syphacia* Seurat, but in a few individuals a slight cuticular thickening, apparently of a transient nature, is present on the ventral surface, on the inner side of the coil. The head measures 0·02–0·023 mm. in diameter. The mouth is guarded by three lips, each provided with a papilla. The first part of the œsophagus is club-shaped and measures 0·024–0·259 mm. in length and 0·037–0·041 mm. in breadth. The œsophageal bulb is spherical in shape and

measures 0·071–0·078 mm. in diameter. The nerve ring is situated at a distance of 0·115–0·12 mm. from the anterior end. The excretory pore is situated in the post-œsophageal region at a distance of 0·54–0·58 mm. from the anterior extremity. The caudal extremity of the male is coiled ventrally (as described above), and narrows suddenly behind the cloaca, ending in a thin long process. The distance from the cloaca to the tip of the posterior

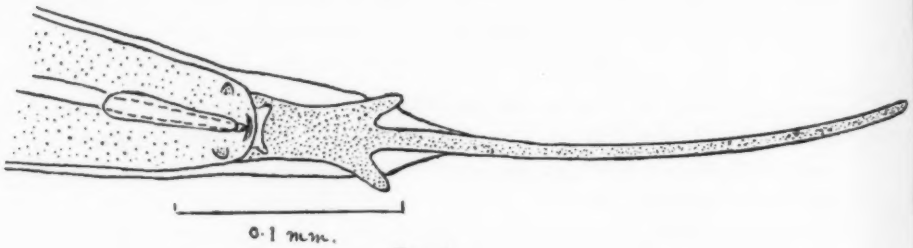

FIG. 1.

Wellcomia taylori, sp. nov., male ; caudal extremity, ventral view.

extremity is 0·28–0·296 mm. There is a pair of pre-anal and two pairs of post-anal papillæ. The first pair of post-anal papillæ is situated a little above the posterior lip of the cloaca ; the second pair is larger and to some extent sustains the caudal alæ. The spicule is long and slender, measuring 0·15–0·159 mm. in length ; the accessory piece is ' tadpole-shaped ' and measures 0·064–0·07 mm. in length. The caudal alæ begin at the level of the cloaca and end a little behind the second pair of post-anal papillæ.

The female is relatively stout and measures 3·47–4·22 mm. in length and 0·213–0·256 mm. in breadth. There are no cervical alæ but the cuticle is inflated in the anterior part of the œsophageal region. Transverse striations on the cuticle are 0·013–0·017 mm. apart. The œsophagus, exclusive of its bulb, is club-shaped and measures 0·321–0·356 mm. in length and 0·06–0·069 mm. in breadth. The œsophageal bulb is spherical and has a diameter of 0·111–0·133 mm. The œsophageal tissue contains granules of a black pigment on account of which it is visible as a black streak to the naked eye, even in uncleared specimens. The nerve ring is situated at a distance of 0·103–0·112 mm. from the anterior end. The vulva is located in the anterior fourth of the body at a distance of 0·852–1·065 mm. from the anterior extremity. The vagina is not extruded from the body, as in other species of *Wellcomia*. The eggs are elongated and shaped somewhat like date stones, convex on one side and straight or slightly concave on the other. They measure 0·068–0·793 × 0·017–0·021 mm. The tail is elongated, 0·480–0·532 mm. in length, and ends in a probulate point. The cuticle of the tail

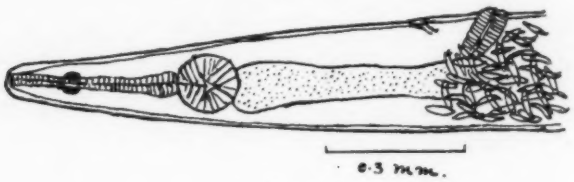

FIG. 2.

Wellcomia taylori, sp. nov., female ; anterior extremity, lateral view.

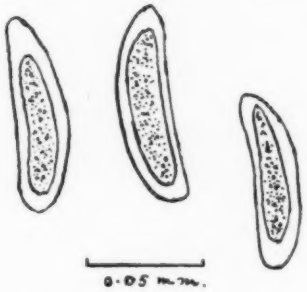

FIG. 3.

Wellcomia taylori, sp. nov. ; ova.

is smooth and there are no spiral markings on it. The excretory pore is situated on the ventral surface, a little in front of the vulva, at a distance of 0·746–0·879 mm. from the anterior end.

Host : Himalayan flying squirrel (*Pteromys inornatus* Geoffroy).

Location : Cæcum.

Locality : Mukteswar, Kumaon Hills (7,500 feet above the sea-level), Western Himalayas.

Among the known species of *Wellcomia* the present species comes nearest to *W. hilgerti* (Seurat, 1914), which it re embles in the absence of spiral markings on the tail of the female and general arrangement of the caudal papillæ of the male, but differs from it in the absence of the vaginal extrusion, and considerably greater prolongation of the tail in the male. Moreover, there are important differences in size of the body and relative measurements of the various organs.

The present species is dedicated to Mr. W. Taylor, Principal, Punjab Veterinary College, Lahore, in gr..teful recognition of his kind help and encouragement which enabled the author to start his scientific career.

REFERENCES.

Baylis, H. A. .. "Notes on some Parasitic Nematodes (i) On the genus *Wellcomia* Sambon, and a New Species of that Genus," *Ann. Mag. nat. Hist.*, 1922, Ser. 9, **9**, 494.

———— .. *Fauna of British India, Nematoda*, 1936, **1**, 206.

——, and Daubney, R. .. "Report on Parasitic Nematodes in the Collection of the Zoological Survey of India," *Mem. Ind. Mus.*, 1922, **7**, 1–263.

Hall, M. C. .. "Nematode Parasites of Mammals of the Orders *Rodentia, Lagomorpha* and *Hyracoidea*," *Proc. U.S. Nat. Mus., Washington*, 1916, **50**, 1–258.

Price, E. W. .. "*Wellcomia compar* (Leidy) the correct name for *Oxyuris compar* Leidy, 1856," *J. Parasit.*, 1930, **16**, 159.

Seurat, L. G. .. "Sur L'accouplement precoce d'un Oxyure," *Compt. rend. Acad. Sci.*, Paris, 1914, **159(22)**, 755–57. (*See* also Seurat, 1915.)

———— .. "Nematodes Paarasites. Expedition de Mm. Walter Rothschild, E. Hartet et C. Hilgert dans le sud Algerien," *Novitates Zoologicæ*, 1915, **22**, 1.

Smith, Allen J. .. "Synopsis of the studies in metazoan Parasitology in McManus Laboratory of Pathology, Univ. of Pennsylvania," *Univ. Penn. M. Bull*, 1908, **20**(12), 262–82.

Travassos, L. .. "Informacoes sobre a fauna helmintologica de matto Grosso. Oxyuroidea-Oxyuridæ," *Fohl. Med.*, 1923, **4**, 29.

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